Monitoring Relative Abundance of American Shad in Virginia Rivers

2007 Annual Report

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Summary

- A staked gill net was set and fished each week on the James, York and Rappahannock Rivers in the spring of 2007. This was the tenth year of monitoring in a stock assessment program for American shad that was initiated in spring 1998. Our approach has been to establish a sentinel fishery, based on traditional methods used prior to the imposition of the current in-river moratorium in 1994. The primary objective is to establish a time series of catch rates that can be compared to historical data recorded in logbooks voluntarily submitted by commercial fishers when the staked gill net fishery was active. The monitoring provides information on the current status of shad stocks relative to conditions prior to the moratorium dating to 1980 in the James and Rappahannock rivers. In the case of the York River, monitoring allows assessment of current status relative to catch rates recorded in the 1980's and the 1950's. The monitoring data were used in a coast-wide stock assessment for American shad conducted by the Atlantic States Marine Fisheries Commission and approved in 2007.

- Sampling occurred for ten weeks on each river (26 February to 6 May 2007). After 9 April, post-spawning fish were mixed with pre-spawning fish in the catch on the York and James Rivers. After 30 April, post-spawning fish were mixed with pre-spawning fish on the Rappahannock River. Only pre-spawning fish were included in the calculation of catch indexes for each river. A total of 634 pre-spawning female American shad (928.1 kg total weight) were captured. The 2007 total catch increased from the 2006 catch (413 pre-spawning females weighing 600.7 kg). The 2006 catch was the lowest observed since monitoring began in 1998.

- Total numbers and weights of females in 2007 were highest on the York (n=272, 400.6 kg) and James (n=235, 332.9 kg) Rivers. The lowest catch of females was on the Rappahannock River (n=127, 194.5 kg). Numbers of males captured were: James, 62; York, 47; Rappahannock River, 26. The total weight of males captured on all rivers was 158.99 kg.

- Based on age estimates from scales, the 2002 (age 5) year class of female American shad was the most abundant on the James, York, and Rappahannock Rivers, with peak age-specific seasonal catch rates exceeding 0.0234 kg/m, 0.0263 kg/m, and 0.0148 kg/m respectively. The 2003 (age 4) year class was also abundant on all three rivers with seasonal catch rates exceeding 0.0109 kg/m. Total instantaneous mortality rates of females calculated from age-specific catch rates were: York River, 0.94 (r^2= 0.94); James River, 1.39 (r^2= 0.98); and Rappahannock River, 0.69 (r^2= 0.99). Total instantaneous mortality rates of males calculated from age-specific catch rates were: Rappahannock River, 0.35 (r^2= 0.95); York River, 0.55 (r^2= 0.92). Total instantaneous mortality was not estimated for James River males.

- Otoliths of 152 American shad captured on the James River were scanned for hatchery marks. The proportion of the sample with hatchery marks on the James River was 31.6 % (48 of 152 fish). In 2005 and 2006 the prevalence of fish with hatchery marks was 23.8% and 10.3%, respectively.

- The geometric mean catch (standard deviation and number of seine hauls in parentheses) of juvenile American shad captured in daylight seine hauls in 2007 was: James River, 0.04 (0.155, 20); Rappahannock River, 0.16 (0.354, 35); York River (inclusive of Pamunkey and Mattaponi rivers), 0.12 (0.370, 88); Mattaponi River, 0.24 (0.487, 47); and Pamunkey River, 0 (0, 36).

- Twenty-five species of fishes were taken as by-catch in the staked gill net monitoring gear for a total of 27,372 specimens. The total number of striped bass captured was 6,667 (James River, n=3,157; York River, n=1,577; Rappahannock River, n=1,933). Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River, 30.5%; York River, 28.8%; and the Rappahannock River, 39.7%.

- In recent years of monitoring (2000-2005), mean age of females has increased as a result of lower proportions of younger fish in the monitoring catch. In 2006, mean age of females decreased sharply, signaling an influx of younger fish on all three rivers. Abundance of juvenile fish was low in 1997-2002 in the York and Rappahannock rivers, suggesting recruitment failure in some years. Recruitment is below levels of detection on the James River in most years. The 1997-2003 age classes are now recruiting to the monitoring gear.

- A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2007 and for each year of the historical record of staked gill net catches on each river. On the York River, the seasonal catch index in 2007 (5.04) increased from the 2006 value, which was the lowest recorded value since monitoring began in 1998. The 2007 value was below the peaks observed in previous years. During the nine years of monitoring, the index has been variable with high values (>12) in 1998 and 2001 and lower values (<9) in other years. The geometric mean of the historical data during the 1980's on the York River is 3.22. The geometric mean of the current monitoring data is higher (7.17) but this mean is lower than the geometric of catch indexes from log book records in the 1950s (17.44). These older data were adjusted for differences in the efficiency of multifilament and monofilament nets using the results of comparison trails in 2002 and 2003.

- On the James River, the 2007 index (4.45) increased from the lowest value recorded in 2006 (1.74). Index values in 2000-2005 were higher than those in 1998 and 1999 (2.57 and 2.99, respectively). The geometric mean of the historical data during the 1980's on the James River is 6.40 while the geometric mean of the current monitoring data is lower (4.72). The stock continues to be dependent on hatchery inputs since recruitment of wild fish is negligible based on juvenile abundance surveys.

- The catch index on the Rappahannock River in 2007 (2.60) decreased slightly from the 2006 value (3.01). The geometric mean of the historical data during the 1980's on the Rappahannock River is 1.45. The geometric mean of the current monitoring data is higher (3.11).

Preface

Concern about the decline in landings of American shad (*Alosa sapidissima*) along the Atlantic coast prompted the development of an interstate fisheries management plan (FMP) under the auspices of the Atlantic States Marine Fisheries Management Program (ASMFC 1999). Legislation enables imposition of federal sanctions on fishing in those states that fail to comply with the FMP. To be in compliance, coastal states are required to implement and maintain fishery-dependent and fishery-independent monitoring programs as specified by the FMP. For Virginia, these requirements include spawning stock assessments, the collection of biological data on the spawning run (e.g., age-structure, sex ratio, and spawning history), estimation of total mortality, indices of juvenile abundance, biological characterization of permitted by-catch and evaluation of restoration programs by detection and enumeration of hatchery-released fish. This annual report documents continued compliance with Federal law. Since 1998, scientists at the Virginia Institute of Marine Science have monitored the spawning run of American shad in the James, York and Rappahannock rivers. The information resulting from this program is reported annually to the ASMFC, has formed the basis for a significant number of technical papers published in the professional literature, formed the basis for a recent coast-wide stock assessment and peer review for American shad (ASMFC 2007a, 2007b) and is contributing substantially to our understanding of the status and conservation of this important species.

A number of individuals make significant contributions to the monitoring program and the preparation of this report. Commercial fishermen Tony Kellum, Raymond Kellum, Marc Brown and Jamie Sanders construct, set, and fish the sampling gear and offer helpful advice. They have participated in the sampling program since its beginning in 1998. Their contributions as authors of historic log books of commercial catches during the 1980s and as expert shad fishermen are essential elements of the monitoring program. In 2007, the staff and students of the Virginia Institute of Marine Science who participated in the program were: B. Watkins, P. Crewe, A. Rhea, R. Harris, T. Tuckey, and S. Upton. Their dedication, consistent attention to detail and hard work in the field and in the laboratory are appreciated. B. Watkins determined ages and hatchery origins of fish. Fish products from the sentinel fishery are donated to the Food Bank of Newport News, Virginia. We offer our thanks to Mr. Bud Davenport who facilitates this donation and to the Hunters for the Hungry (Virginia Hunters Who Care) organization for their assistance.

Introduction

A moratorium on the taking of American shad (*Alosa sapidissima*) in the Chesapeake Bay and its tributaries was established by the Virginia Marine Resources Commission (VMRC) beginning 1 January 1994. The prohibition applied to both recreational and commercial fishers, and was imposed at a time when commercial catch rates of American shad in Virginia's rivers were experiencing declines. At the time, data from the commercial fishery were the best available for assessing the status of individual stocks. Catch-per-unit-effort (CPUE) data were compiled from logbooks that recorded landings by commercial fishermen using staked gill nets at various locations throughout the middle reaches of the James, York and Rappahannock rivers. The logbooks were voluntarily provided to the Virginia Institute of Marine Science (VIMS) during the period 1980-1993, and subsequently used in an assessment of the status of American shad stocks along the Atlantic coast by the Atlantic States Marine Fisheries Commission (ASMFC) (ASMFC 1999).

Immediately following the moratorium, there were no monitoring programs that provided direct assessment of stock recovery. The ban on in-river fishing in Virginia remained in effect, creating a dilemma for managers who needed reliable information in order to make a rational decision on when the in-river ban could be lifted safely. To address this deficiency, a method of scientific monitoring was proposed to estimate catch rates relative to those recorded before the prohibition of in-river fishing in 1994. This monitoring program began in 1998 and consisted of sampling techniques and locations that were consistent with, and directly comparable to, those that generated historical logbook data collected by VIMS during the period 1980-1992 in the York, James and Rappahannock rivers. The results of the tenth year in the sampling program (2007) are reported in this document and compared to some results in previous years of monitoring. Detailed results of the first nine years of sampling (1998-2006) are reported in previous annual reports (Olney and Hoenig 2000a, 2000b; Olney and Hoenig 2001a; Olney and Maki 2002; Olney 2003a, 2004, 2005; Olney and Delano 2006; Olney and Walter 2007). Copies of these reports are available upon request.

In addition to the objective of assessment of the status of stocks in Virginia's rivers, there are other significant information needs. First, extensive efforts are being made to rehabilitate shad stocks through release of hatchery-raised fish. Evaluating the success of these programs requires determination of the survival of the stocked fish to adulthood. Second, there is an extensive time series of observations on juvenile shad abundance from push net surveys in the York River and seine surveys in the James, York and Rappahannock rivers. These juvenile index data could have utility for predicting future spawning run sizes, detecting years of failed recruitment and confirming the health of the stocks.

These ongoing studies of American shad in Virginia waters are significant to recreational fisheries for at least three reasons.

- American shad fight well when angled using light tackle. Harvest of American shad by the recreational fishery in the James, York and Rappahannock rivers is

prohibited but recreational fishing is popular in Florida, North Carolina, Maryland and several other states where these bans do not exist. Anecdotal information suggests that there were historical recreational fisheries for American shad on the James, Mattaponi and Rappahannock rivers. Currently, many anglers catch and release American shad and legally harvest hickory shad (*Alosa mediocris*) on the James River near Richmond, the Mattaponi River above Walkerton, and the Rappahannock River near Fredericksburg. Recreational fishing also occurs on the Nottoway and Blackwater rivers near Franklin, Virginia. These rivers do not drain into the Chesapeake Bay and the ban on harvest does not apply to these spawning stocks. Continued development of a recreational shad fishery in Virginia could constitute an important opportunity to expand or restore recreational fishing opportunities if the stocks are rehabilitated and managed carefully.

- American shad are important for trophic and ecological reasons. Spawning site selection by adults as well as the abundance and occurrence of juveniles are closely linked to water quality and the availability of good fish habitat. Young shads and river herrings (*Alosa*) form an important prey group for striped bass and other recreationally important species in Chesapeake Bay. The decaying carcasses of post-spawning anadromous fishes are known to play an important role in nutrient and mineral recycling in riverine and estuarine systems. In recent years, there have been shifts in community structure in the major tributaries to the Chesapeake Bay with striped bass and gizzard shad numbers increasing greatly. Monitoring changes in abundance of key species is essential for understanding community dynamics.

- Monitoring the shad spawning run using historic gear also allows for a description of the by-catch associated with a commercial fishery for shad in Virginia's rivers. This is important for determining the impact of the commercial fishery for shad on other recreationally important species, especially striped bass, if the ban on commercial and recreational harvest was lifted.

Background

Herring and shad have supported recreational and commercial fisheries along the east coast of the United States and within the Chesapeake Bay since colonial times. They also play a vital ecological role. Juvenile *Alosa* are an important prey species for striped bass and other recreational species while they remain on their freshwater and upper estuarine nursery grounds. In the autumn they move to coastal waters where they are subjected to predation by many types of marine piscivores until they return to their native streams to spawn for the first time at ages 3 to 7 (Maki et al., 2001, Limburg et al. 2003).

Management and conservation of Virginia's stocks of American shad date to colonial times. Before Virginia was settled, Native Americans caught American shad in large quantities using a seine made of bushes (Walburg and Nichols 1967). Shad were so

plentiful that they could be speared with pointed sticks as they swam on the flats (VCF 1875). Remains of American shad and Atlantic sturgeon have been found in recent archaeological digs at Jamestown, the site of first English settlement (get reference). Apparently, these species were important dietary components during the starving time in 1609. The early settlers used haul seines, and utilized shad as a major food supply (Walburg and Nichols 1967). By 1740, shad were less abundant, presumably due to fishing and obstructions that prevented the fish from reaching their spawning grounds. Concerned colonists passed laws requiring the removal of dams or the building of fish passages, and prohibiting hedges and other obstructions (VCF 1875). In 1771, the Virginia Assembly passed a law requiring that a gap for fish passage be built in dams adhering to specific dimensions, and that it be kept open from February 10 to the last day of May. However, due to the approaching conflict of the Revolutionary War, the law was never enforced (VCF 1875).

The shad fishery of Chesapeake Bay became important about 1869, and developed greatly in the ensuing years. Fishing gear used included haul seines, pound nets, and staked gill nets (Walburg and Nichols 1967). Catches reached a low in 1878, and the U.S. Fish Commission and Virginia Commission of Fisheries instituted an artificial hatching program in 1875. By 1879 the fishery began to improve, and the increase in catches led biologists to believe that the shad fishery was largely dependent upon artificial propagation. However, by the early 1900's the decline in shad harvests resumed despite improved hatching methods and increased numbers of fry released (Mansueti and Kolb 1953).

Stevenson (1899) provided important information on catch and effort in the American shad fishery in Virginia during the fishing season in 1896. Using an average weight per female of 1.7 kg, the following fishery statistics can be obtained from his report. On the lower James River, 60,750 females (approximate weight: 103,278 kg) were landed by staked gill nets totaling approximately 79,263 m in length. On the York River, 28,232 females (approximate weight: 49, 994 kg) were landed by staked gill nets totaling approximately 5,874 m in length. The value of these roe shad in 1896 dollars was approximately $4,000. On the Rappahannock River, 104,118 females (approximate weight: 177,000 kg) were landed by staked gill nets totaling 24,694 m in length. The local value of these shad was approximately $8,000. Seasonal catch averages (total female weight/total length of net) depict higher seasonal catch rates on the York River (8.5 kg/m) and the Rappahannock River (7.2 kg/m) than on the James River (1.3 kg/m) in 1896. Stevenson (1899) also reported large catches of American shad on the Chickahominy and Appomattox rivers in 1896.

Nichols and Massmann (1963) estimated total catch, fishing rate, escapement and total biomass of American shad in the York River in 1959 and summarized landings during the period 1929-1959. Landings were low (~100,000 lbs annually) in the 1930's but rose abruptly in the years following the world war, reaching the highest levels (400,000-700,000 lbs annually) in the 1950's. During this latter period of higher annual landings, catch-per-unit-effort remained relatively constant. Of the major gears used in the fishery in 1959 (pound nets, haul seines, fyke nets, stake gill nets and drift gill nets),

gill nets (both stake and drift) accounted for the greatest effort expended and the highest total catches. A tagging study conducted in 1959 produced the following estimates: overall fishing rate, 55.2%; estimated population biomass, 838,892 lbs; and estimated escapement, 375,768 lbs. Using catch and effort data, Nichols and Massmann (1963) estimated population biomass for the period 1953-1959 to range from 839,000-1,396,000 lbs. Sex composition of the catch was not reported. Using the average female weight of 3.2 lbs in 1959 and assuming that the sex ratio of the catch was 1:1, the estimated total number of females in the York River in 1953-1959 ranged from about 131,000-218,125.

Today, many American shad stocks along the eastern seaboard of the United States are in low abundance (Figure 1). Large catches no longer occur as they did at the turn of the century and in many areas, including Chesapeake Bay, harvest is banned or severely restricted. Commercial American shad landings in Virginia decreased from 11.5 million pounds in 1897 to less than a million pounds in 1982. Over-fishing, dam construction, pollution, and loss of natural spawning grounds are a few of the factors that may be related to this decline. Historically, the majority of American shad were captured within the rivers. Beginning in 1984, the largest proportion of American shad taken in Virginia's fishery was captured offshore. The overall impact of this shift in the fishery on egg production and annual recruitment of Virginia stocks is unknown. Genetic studies of the catch composition of Virginia and Maryland's coastal landings have suggested that the intercept fishery claimed a highly variable proportion of Virginia's riverine stocks (Brown and Epifanio 1994). American shad were pursued by recreational fishermen in Virginia in the past, but the extent and success of this activity is not easily assessed.

In spring 1994, the Virginia Department of Game and Inland Fisheries (VDGIF) and the US Fish and Wildlife Service (USFWS) began a hatchery-restocking effort in the James and Pamunkey rivers. Adult shad from the Pamunkey River are used as brood stock, eggs are stripped and fertilized in the field, and larvae are reared in the VDGIF hatchery at Stephensville, Virginia, and the USFWS hatchery at Harrison Lake, Virginia. Prior to release, the larvae are immersed in an oxytetracycline (OTC) solution that marks otoliths with a distinctive epifluorescent ring. The initial success of this ongoing program was documented by Olney et al. (2003) who reported that catch rates by monitoring gear increased in 2000-2002 as large numbers of mature hatchery fish returned to the James River. More recently, hatchery prevalence in the James River has decreased, presumably due to a dilution effect caused by the increased abundance of returning unmarked, hatchery progeny. This hypothesis has not been tested, however.

In most years, prevalence of hatchery fish returning as adults to the York system is low (~2-4 % each year; Olney and Hoenig 2000a, 2000b, 2001a; Olney and Maki 2002, Olney 2003a, Olney 2004, Olney 2005). Annual monitoring of the abundance of juvenile *Alosa* (American shad, hickory shad, blueback herring and alewife) was conducted on the Pamunkey River system during 1979-2002. After 1995, juveniles bearing the OTC mark were collected by VIMS and VDGIF. The data show that hatchery-released larval shad constituted 0.1-8 % of the total catch of juveniles on the Pamunkey River during the 4-y period (1995-1999). VDGIF personnel also began a new hatchery-release program on the upper Rappahannock River in 2005. The restoration program uses progeny of

Potomac River brood stock. The goal of this program is to restore American shad to historical spawning areas that were previously blocked by Embrey Dam.

Prior to 1991, there were no restrictions on the American shad commercial fishery in Virginia rivers and the Chesapeake Bay. A limited season (4 February - 30 April) was established for 1991 by the Virginia Marine Resources Commission (VMRC), and kept in place in 1992. In 1993, a further limitation to the season was established (15 March - 15 April 1993). However, due to bad weather conditions, the season was extended through 30 April. A complete moratorium was established in 1994. At that time, the regulation stated:

> "On and after 1 January 1994 it shall be unlawful for any person to catch and retain possession of American shad from the Chesapeake Bay or its tidal tributaries." (VMRC Regulation 450-01-0069).

In 1997 and 1998, during a series of public hearings, commercial fishing interests asked that the in-river ban on shad fishing be lifted. This proposal was opposed by the VMRC staff, scientists of the Virginia Institute of Marine Science, and representatives of various other public and private agencies. The Commission decided to leave the ban in place but also decried the lack of information necessary to assess the recovery of Virginia stocks of American shad. The current monitoring project began in the spring of 1998 in response to the VMRC's request for information.

In spring 2003, Virginia imposed a 40% reduction in effort on the ocean intercept (gillnet) fishery prosecuted on the coast. This reduction in effort was mandated by the ASMFC. According to Amendment 1 (ASMFC 1999), "[States] must begin phase-out reduction plans for the commercial ocean-intercept fishery for American shad over a five-year period. States must achieve at least a 40% reduction in effort in the first three years, beginning January 1, 2000." The Virginia offshore fishery was closed on 31 December 2004.

In spring 2006, the VMRC authorized a limited by-catch fishery for American shad in specific areas. Fishers with special permits were allowed to possess fish caught in anchored or staked gill nets when fished in areas above the first bridge on the James, York and Rappahannock rivers. Limits were imposed on this take (10 fish per boat per day) and fishers were required to phone in a weekly report of the harvest. In addition, American shad by-catch could only be possessed if equal numbers of other species (such as striped bass) were also landed. This by-catch authorization subsequently was extended into the 2007 fishing season (see Appendix 1).

Current Information

Historic and current catch data can be accessed through the VMRC website (http://www.mrc.virginia.gov/). Annual monitoring of the abundance of juvenile *Alosa* (American shad, hickory shad, blueback herring and alewife) was conducted on the York River system with a push net developed in the late 1970s (Kriete and Loesch, 1980). The

data record extends back to1979 but sampling was not conducted during 1987-1990. The push net survey was terminated in 2002 when it was determined that the survey results were highly correlated with those of the striped bass seine survey (Wilhite *et al.*, 2003). Although fewer individual fish are collected each year in the seine survey as compared to the evening push net survey, the seine survey has larger geographic coverage (all three rivers in Virginia vs. the Mattaponi and Pamunkey Rivers only) and the data record is uninterrupted since 1979.

Since the American shad monitoring program at VIMS began in 1998, 22 papers on various aspects of the biology of American shad and the VIMS stock assessment program have appeared in peer-reviewed journals (Maki et al., 2001a; Olney et al., 2001; Olney and Hoenig, 2001b; Maki et al., 2002; Bilkovic et al., 2002a; Bilkovic et al., 2002b; Olney and McBride, 2003; Olney et al., 2003; Walter and Olney, 2003; Wilhite et al., 2003; Olney 2003b; Hoffman and Olney, 2005; McBride et al., 2005; Maki et al., 2006; Olney et al., 2006; Olney et al., 2006; Hoffman et al. 2007; Hoffman et al. 2007a; Hoffman et al. 2007b; Hoffman et 2008, Walther et al. 2008; Hoenig et al. 2008). Reprints of these papers are available on request.

VIMS' authors contributed to three peer-reviewed sections to the recent stock assessment for American shad (Olney 2007; Olney et al. 2007b; Carpenter et al 2007). In addition, manuscripts based on two completed theses describing the spawning grounds of American shad in the James River (Aunins 2006) and seasonal fecundity of shad in the York River (Hyle 2004) are in preparation. Two studies form the basis for a thesis and a dissertation that are in progress and are supported in part by the monitoring program: a validation of age determination of American shad using otolith isotopes as natural tags (Sally Upton, see Appendix 2) and a study of the population dynamics of juvenile *Alosa* in Virginia rivers (Troy Tuckey, see Appendix 3). Finally, our monitoring data have been used in a recent revision of the on-line Chesapeake Bay Report presented annually by the Chesapeake Bay Program of the Environmental Protection Agency (Appendix 4).

Objectives

The primary objectives of the monitoring program have remained largely unchanged since 1998: (1) to establish time series of relative abundance indices of adult American shad during the spawning runs in the James, York and Rappahannock rivers; (2) to relate contemporary indices of abundance of American shad to historical log-book data collected during the period 1980-1992 and older data if available; (3) to assess the relative contribution of hatchery-reared and released cohorts of American shad to adult stocks; (4) to relate recruitment indices (young-of-the-year index of abundance) of American shad to relative year-class strength and age-structure of spawning adults; and (5) to determine the amount of by-catch of other species in the staked gill nets.

In 2006 and 2007, an additional objective was to monitor a new by-catch fishery for American shad established by the VMRC. The results of this monitoring are appended as a report to the American shad and river herring technical committee as Appendix III.

Methods

The 2007 sampling methods for the monitoring program were the same as those in 1998-2006 (see Appendix III for additional methods used to monitor the by-catch fishery). In 1998, a sentinel fishery was developed that was as similar as possible to traditional shad fishing methods in the middle reaches of Virginia's rivers. When the in-river fishing moratorium was imposed in 1994, commercial fishermen who held permits for existing stands of staked gill nets (SGNs) were allowed to retain priority rights for the locations of those stands in the various rivers. VIMS has records of the historic fishing locations (Figures 2-4), and one of these locations on each river (the James, York and Rappahannock) was used to monitor catch rates by SGN's in 1998-2000. Three commercial fishermen were contracted to prepare and set SGN poles, hang nets, replace or repair poles or nets, and set nets for each sampling event during the monitoring period. Two of these commercial fishermen, Mr. Raymond Kellum (Bena, Virginia) and Mr. Marc Brown (Rescue, Va), were authors of the historical logbooks on the James and York rivers. However, authors of historic logbooks on the Rappahannock River were either retired or not available. Thus, we chose a commercial fisherman (Mr. Jamie Sanders, Warsaw, Va) who had previous experience in SGN fishing but who had not participated in the shad fishery on the Rappahannock River in the 1980's. Scientists accompanied commercial fishermen during each sampling trip, and returned the catch to the laboratory.

One SGN, 900 ft (approximately 273 m) in length, was set on the York and James rivers (Figures 5-6). One staked gill net, 912 ft (approximately 276 m) in length, was set on the Rappahannock River (Figure 7). Locations of the sets were as follows: lower James River near the James River Bridge at river mile 10 (36^0 50.0' N, 76^0 28.8' W); middle York River near Clay Bank at river mile 14 (37^0 20.8' N, 76^0 37.7' W); and middle Rappahannock River near the Rappahannock River bridge (at Tappahannock) at river mile 36 (37^0 55.9' N, 76^0 50.4' W). Historical catch-rate data on the York and James rivers were derived from nets constructed of 4 7/8" stretched-mesh monofilament netting, while historic data from the Rappahannock River were based on larger mesh sizes (nets constructed of 5" stretched-mesh). To insure that catch rates in the current monitoring program were comparable to logbook records, nets on the York and James rivers were constructed of 4 7/8" (12.4 cm) stretched-mesh monofilament netting, while nets on the Rappahannock River were constructed of 5" (12.7 cm) netting. Panel lengths were consistent with historical records (30 ft each on the James and York rivers; 48 ft each on the Rappahannock River). Each week, nets were fished on two succeeding days (two 24-h sets) and then hung in a non-fishing position until the next sampling episode. Occasionally, weather prevented the regularly scheduled sampling on Sunday and Monday, and sampling was postponed, canceled or re-scheduled for other days. In 2007, sampling occurred for ten weeks on each river (26 February to 6 May 2007). Surface water temperature and salinity were recorded at each sampling event.

Individual American shad collected from the monitoring sites were measured and weighed on a Limnoterra FMB IV electronic fish measuring board interfaced with a Mettler PM 30000-K electronic balance. The board recorded measurements (fork length and total length) to the nearest mm, received weight input from the balance, and allowed manual input of additional data (such as field data and comments) or subsample designations (such as gonadal tissue and otoliths) into a data file for subsequent analysis. Catches of all other species were recorded and enumerated on log sheets by observers on each river and released. For striped bass (*Morone saxatilis*), separate records were kept of the number of live and dead fish in the nets and released (if alive) or returned to the laboratory (if dead).

Sagittal otoliths were removed from samples of adult American shad, placed in numbered tissue culture trays, and stored for subsequent screening for hatchery marks. To scan for hatchery marks, otoliths were mounted on slides, then ground and polished by hand using wet laboratory-grade sandpaper. Otolith scanning was performed by B. Watkins (VIMS) in 2005-2007. Scanning in previous years was performed by D. Hopler (VDGIF), J. Goins (VIMS) and G. Holloman (VIMS).

Scales for age determination were removed from a mid-lateral area on the left side posterior to the pectoral-fin base of each fish. Scales were cleaned with a dilute bleach solution, mounted and pressed on acetate sheets, and read on a microfilm projector by one individual (B. Watkins, VIMS) using the methods of Cating (1953). Ages were determined by a different reader in 1998-2002 (K. Maki). To insure consistency, B. Watkins has re-aged all scale samples collected during the monitoring program.

An ASMFC age-determination workshop using known age fish from the Susquehanna River system was held at VIMS in August 2004 to test the validity of scale-age techniques (McBride *et al*., 2005). As a result of this analysis, the ASMFC stock assessment subcommittee chose to moderate its use of age data in the 2007 coastwide assessment but not abandon those data entirely (Olney 2007). One recommendation of the workshop was to validate age determination in all major stocks. In an ongoing study (in collaboration with Dr. Simon Thorrold, Woods Hole Oceanographic Institution), VIMS graduate student Sally Upton is using stable isotope as natural markers to distinguish the 2002 year class of returning adults (Appendix 2). These samples will be used to track the maturation and recruitment of this year class to the monitoring gear and to compare isotope-based, scale-based and otolith-based ageing methods.

Catch data from each river were used to calculate a standardized catch index (the area under the curve of daily catch rate versus time of year). The catch index, the duration of the run in days, the maximum daily catch rate in each year and the mean catch rate in each year were compared to summaries of historical logbook data to provide a measure of the relative size of the current shad runs. In the historical data, catches are reported daily through the commercial season with occasional instances of skipped days due to inclement weather or damaged fishing gear. In the current monitoring data, catches on two successive days are separated by up to five days (usually Tuesday-Saturday) in each week of sampling. In some rare cases, catches are separated by more

than five days. To compute the catch index, we estimated catches on skipped days using linear interpolation between adjacent days of sampling.

Results

Catches of American shad by staked gill nets in 2007

Fishing days, numbers of American shad captured, catch rates (males and females) and length frequencies are reported in Tables 1-8 and Figures 8-15. After 9 April 2007 on the York and James Rivers and after 30 April on the Rappahannock River, post-spawning American shad were mixed with pre-spawning ("roe") fish in the catch (Table 2). Post-spawning fish were identified macroscopically and microscopically depending on gonad condition. Since the historic fishery was a roe fishery and spent or partially spent fish were not routinely captured or marketed in the historic fishery, post-spawning fish were removed from the monitoring sample.

A total of 791 American shad (135 males; 656 females) were captured. The total weight of the sample was 1116.8 kg (male, 158.99 kg; female, 957.77 kg). Catches in 2007 were lowest on the Rappahannock River (155 total fish, 26 males and 129 females), higher on the James River (301 total fish, 62 males and 239 females) and highest on the York River (335 total fish, 47 males and 288 females).

On the York River, catches of females peaked on 12 March – 10 April when catch rates usually exceeded 0.04 fish/m or 0.05 kg/m. During that period on the York River, 79% (215 of 272) of the total number of females was captured. Surface temperatures during this time ranged from 8.1^{o}C - 14.8^{o}C. The largest catch of pre-spawning female American shad on the York River (45 fish) occurred on 20 March when the surface temperature was 8.3^{o}C (Figure 16). On the James River, catches of females peaked between 11 March and 10 April when catch rates were normally above 0.04 fish/m or 0.06 kg/m. During that period on the James River, 86% (203 of 235) of the total number of females was captured. Surface temperatures during this time ranged from 7.7^{o}C - 14.9^{o}C. The largest catch of pre-spawning female American shad on the James River (29 fish) occurred on 25 March when the surface temperature was 12.0^{o}C (Figure 16). Catches of females on the Rappahannock River peaked on 9 April – 29 April when catch rates exceeded 0.03 fish/m or 0.04 kg/m. During that period on the Rappahannock River, 66% (85 of 129) of the total number of females was captured. Surface temperatures during this time ranged from 9.6^{o}C - 18.1^{o}C. The largest catch of pre-spawning female American shad on the Rappahannock River (24 fish) occurred on 10 April when the surface temperature was 10.0^{o}C (Figure 17). As in previous years of monitoring, numbers and catch rates of males were lower than catch rates of females throughout the period. Sex ratios (males:females) were: York River, 1:5.8; James River, 1:3.8; Rappahannock River, 1:4.9. It is important to note that the monitoring gear mimics an historical fishery that was selective for mature female fish.

The duration of the spawning run is defined as the number of days between the first and last observation of a catch rate that equals or exceeds 0.01 female kg/m. In 2007, the catch rate on the York River was equal to 0.01 female kg/m when sampling was initiated; therefore the spawning run duration estimate for this year is slightly conservative. The 2007 spawning run duration was estimated to be 58 days on the James River (3 March - 30 April), 70 days on the York River (26 February – 6 May), and 64 days on the Rappahannock River (4 March – 6 May).

Biological characteristics of the American shad catch in 2007

Age, mean length (mm TL) and mean weight (g) of American shad in staked gill nets are summarized in Tables 9-10. Patterns of mean age are depicted in Figure 21 and 22. Mean total length at age of males and females ranged from 418 – 497 mm TL and 453.5 – 589 mm TL, respectively. Mean weight at age of males and females ranged from 0.81 – 1.47 kg and 1.15 – 2.62 kg, respectively.

Using scale-based ageing methods, we estimated that the 2003, 2002 and 2001 year classes (ages 4, 5 and 6) of female American shad were the most abundant on all three rivers (Table 11). On the James River, six age classes of females were represented (1999–2004, ages 3-8) and the sample was dominated by age-5 fish (45.5% of the total that was aged). On the York River, eight age classes of females were represented (1997-2004, ages 3-10) and the sample was dominated by age-5 fish (48.9% of the total that was aged). On the Rappahannock River, six age classes of females were taken (1998, 2000-2004, ages 3-7 and 9) and the sample was dominated by age-5 fish (48.2% of the total that was aged). The 2001 and 2002 year classes of males were the most abundant on the York, James, and Rappahannock Rivers, respectively (Table 12). These year classes (ages 5-6) of male American shad constituted 67.6% (York River), 81.4% (James River) and 63.2% (Rappahannock River) of the aged sample. Mean age of females in each river have followed similar patterns throughout the period of monitoring, increasing steadily from 2000-2005 and then decreasing in 2006. Mean age increased in 2007 to 5.0 y (James River), 5.3 y (Rappahannock River) and 5.3 y (York River).

Age-specific catch rates of American shad are reported in Tables 11-12. Total instantaneous mortality (Z) was estimated using simple linear regression analysis of the natural log of age-specific catch on the descending limb of the catch curve. Total instantaneous mortality rates of females were: York River, 0.94 (r^2= 0.94); James River, 1.39 (r^2= 0.98); and Rappahannock River, 0.70 (r^2= 0.99). Total instantaneous mortality rates of males calculated from age-specific catch rates were: Rappahannock River, 0.35 (r^2= 0.95); York River, 0.55 (r^2= 0.92). Total instantaneous mortality was not estimated for James River males.

Spawning histories of American shad collected in 2007 are presented in Tables 13-14. On the York River, fish (both sexes combined) ranged in age from 3-11 years with 0 (virgin) to 6 spawning marks. On the James River, fish (both sexes combined) ranged in age from 3-10 years with 0-5 spawning marks. On the Rappahannock River, fish (both sexes combines) ranged in age from 3 – 9 years with 0-4 spawning marks. The

following percentages of fish in each river had at least one prior spawn (termed "repeat spawners"): York River, 56.5% (117 virgins in a sample of 269); James River 43.7% (139 virgins in a sample of 247); Rappahannock River 47.3% (69 virgins in a sample of 131 fish). The percentages of fish with at least one prior spawn on the York River in previous years were: 1998, 40.2%; 1999, 67.3%; 2000, 31.1 %; 2001, 38.8 % ; 2002, 59.5%; 2003, 70.8%; 2004, 70.6%; 2005, 62.4%; 2006, 35.5% (Olney and Hoenig 2000a, 2000b, 2001a; Olney and Maki 2002; Olney 2003a; Olney 2004; Olney 2005; Olney and Delano 2006; Olney and Walter 2007).

Evaluation of hatchery origin of American shad in 2007

James River - Otoliths of 152 American shad captured in staked gill nets on the James River were processed for hatchery marks. The proportion of the 2007 sample with hatchery marks was 31.6% (48 of 152 fish). The biological attributes of these specimens are presented in Table 15. The prevalence of hatchery-reared fish was low in spring 1998 (8.2 %; 14 of 170 adults) and 1999 (3.6 %; 7 of 177 adults). Prevalence rose abruptly in spring 2000 (40.3 %; 156 of 387 adults) and remained near that level through 2003. The 2004 prevalence (32.5%) was lower than all values reported since 2000 (40.2%-51.4%) and continued to decline in 2005 (23.8%). In 2006 hatchery prevalence declined to 10.3%. In most years, fish with hatchery tags from rivers other than the James River were among those counted. These strays were not included in the estimates of hatchery prevalence and are as follows (year captured as an adult, number, river of release): 1999, n= 1, Patuxent River (Maryland); 2000, n= 7, Pamunkey River (Virginia) and Juniata River (Pennsylvania); 2001, n= 3, Pamunkey River, Juniata River, and the western branch of the Susquehanna River (Pennsylvania); 2002, n= 2, Pamunkey River, n= 2 unknown tag; 2005, n=3, tentatively Pamunkey River and Mattaponi River (Virginia); 2007, n=1, Pamunkey River. In 2003, 2004, and 2006 there were no stray fish.

Most hatchery-reared adults taken in 2007 had OTC marks that indicated these specimens were released after 2001. These tags could not be easily differentiated microscopically, so we determined the year of release using scale-determined ages (Tables 13, 15-16). During 2000-2005, hatchery-reared fish captured in the staked gill nets were ages 3-9 (released as fry in 1993-2001). In 1998, hatchery-reared fish captured in our monitoring gear (n= 14) were ages 4 or 5 (released as fry in 1993 or 1994). In 1999, hatchery-reared fish (n=6) were ages 5, 6 or 7 (released as fry in 1992, 1993 or 1994). In these years (1992-1994), hatchery production was below 2 million fry annually (Table 16). Since 1995, hatchery production has exceeded 5 million fry released annually. The highest numbers captured thus far were fish released from 1995-1998. The 1996 year class of hatchery-reared American shad first appeared as age 4, continues to recruit, and is well represented in 2000-2002 samples. This year class has constituted 24.6% of the hatchery-marked catch. The 1997 year class first appeared at age 3 and its contribution (24.8%) is equivalent to the 1996 year class. The 1998 year class first appeared in moderate numbers in 2002 and its recruitment increased substantially in 2003 but dropped in 2004-05. The presence of the 1999 year class peaked in 2004, but decreased in 2005. The decline in catches of fish with hatchery marks declined greatly in 2006. The absence of the 1999 – 2001 hatchery cohorts in 2006 suggests low

survivability of those years. The increase of hatchery fish in 2007 is largely due to the recruitment of the 2002 hatchery cohort. This year class constituted 51.3% of the hatchery-marked catch in 2007 that had determinable ages.

Most hatchery fish captured in the James River in 2000 and 2001 were virgins (no spawning marks on the scales) that had matured at age 4 or 5. In these two years, proportions of the sample that had spawned at least once were: 2000, 28.2 %; 2001, 39.8 %. In 2002, the proportion of repeat spawners increased to 54.2 % (65 virgins in a sample of 142 fish). In 2003 and 2004, the proportions of repeat spawners were 48.2% and 65.1%. In 2005, the proportion of repeat spawners was 30.0% (12 virgins in a sample of 40 hatchery fish). In 2006, there were no repeat spawners (9 virgins in a sample of 9 hatchery fish. In 2007, the proportion of repeat spawners was 35.9% (25 virgins in a sample of 39 hatchery fish).

York River – Otoliths were not scanned for hatchery marks on the York River in 2007. These samples were used in an ongoing natural marker study of the 2002 year class (Appendix 2). The cores of otoliths of York River fish were removed and processed to determine isotopic composition.

Juvenile abundance of American shad

Tables 17 and 18 and Figures 18-20 report index values of juvenile abundance of American shad based on seine surveys (1979-2007) on the James and Rappahannock rivers, the main stem of the York River, the Pamunkey River and the Mattaponi River. The geometric mean catch (standard deviation and number of seine hauls in parentheses) of juvenile American shad captured in daylight seine hauls in 2007 was: James River, 0.04 (0.155, 20); Rappahannock River, 0.16 (0.354, 35); York River (inclusive of Pamunkey and Mattaponi rivers), 0.12 (0.370, 88); Mattaponi River, 0.24 (0.487, 47); and Pamunkey River, 0 (0, 36).

The seine survey data on the James River (Table 17) depict no measurable recruitment during most years. This observation is consistent with those of independent survey results below Bosher's Dam on the James River (VDGIF, T. Gunter, pers. comm.). A few juveniles were captured in 1984, 1998, 2003, 2004, 2006, and 2007. On the Rappahannock River, the highest JAI values (>0.5) were recorded in 1982, 1989, 2003 and 2004. The Rappahannock River time series depicts no measurable recruitment in 1980-1981, 1985, 1988, 1991-1992, 1995 and 2002.

With the exception of 2003 data, juvenile index values based on the seine survey are consistently higher on the Mattaponi River than they are on the Pamunkey River and the York River (Table 18). In the time series, recruitment is highest (>7.0 on the Mattaponi River and >3.0 on the York River) in 1982, 1984-85, 1996 and 2003.

By-catch of striped bass and other species in 2007

Daily numbers and seasonal totals of striped bass and other species captured in staked gill nets are reported in Tables 19-21. Twenty-five species of fishes were taken as by-catch in the staked gill net monitoring gear for a total of 27,372 specimens. The most commonly encountered by-catch species were: gizzard shad (*Dorosoma cepedianum*), striped bass (*Morone saxatilis*), menhaden (*Brevoortia tyrannus*), blue catfish (*Ictalurus furcatus*), Atlantic croaker (*Micropogonias undulatus*), hickory shad (*Alosa mediocris*), white perch (*Morone americana*), and summer flounder (*Paralichthys dentatus*).

The total number of striped bass captured was 6,667 (James River, n=3,157; York River, n=1,577; Rappahannock River, n=1,933). Live striped bass captured in the gear were counted and released. The proportions of dead striped bass on each river were: James River 30.5%; York River, 28.8%; and the Rappahannock River, 39.7%.

Seasonal catch indexes, 1980-1992 and 1998-2007

A seasonal catch index was calculated by estimating the area under the curve of daily catch versus day for the years 1998-2007 and for each year of the historical record of staked net catches on each river (Tables 22-27and Figures 23-25). Seasonal catch indices in 2007 were: York River, 5.04; James River, 4.45; Rappahannock River, 2.60.

Discussion

The staked gill net monitoring program continues to be useful for assessment of stocks of American shad in Virginia. It is the only direct method available to determine the size of the spawning runs relative to what was obtained in the decades prior to the moratorium. The program also provides information for evaluating the hatchery-based restoration program, validating the juvenile index of abundance and for determining the amount of by-catch that could be expected in a commercial fishery if the in-river fishing ban is lifted.

Abrupt increases in the prevalence of hatchery-released adult American shad and higher catch indexes in 2000-2003 indicated a large scale influx of mature virgin hatchery fish since the James River restoration program began in 1992 (Olney *et al.*, 2003). The age composition of the monitoring catch bearing OTC marks during those years was consistent with the timing of releases of large numbers of hatchery fish. The prevalence of hatchery fish increased dramatically in 2000-2003 (40-51%) but has decreased in recent years of monitoring (2004, 33%; 2005, 24%; 2006, 10.3%). The pattern suggests low survival of the 2000 and 2001 hatchery cohort. In 2007 hatchery prevalence once again increased (31.6%) signifying anther influx of mature virgin hatchery fish. Since we cannot distinguish the progeny of hatchery fish using OTC markers, a genetic survey that could identify wild and hatchery components could enhance our understanding of stock dynamics and the extent to which hatchery fish dominate the population. VIMS scientists are cooperating in genetic studies that are

currently underway at Virginia Commonwealth University (A. Aunins and B. Brown, pers. comm.). The monitoring data continue to suggest that a continuation of the hatchery release program at present levels of production in the James River, in combination with fishing moratoria, are critical components of a recovery program for this stock.

In 1998, states were required to develop and submit restoration targets for stocks under moratorium. Virginia presented preliminary targets to the Plan Review Team of the ASMFC Shad and River Herring Management Board with the proviso that these targets would be revised as appropriate historical data became available (see below). Criteria to achieve restoration targets were proposed as either: (1) a three-year period during which the catch index remains at or above the target level in the staked gill net monitoring of the spawning run; (2) a three-year period during which the average catch index is above the target level and the target level is exceeded in two of the years; or (3) a significant increasing trend over a five-year period with the target exceeded in the last two years.

Voluntary logbooks of catches from the York River exist in the archives of the Department of Fisheries Science (Table 24) These historical records from the 1950s form the basis for gear comparison trials conducted in 2002 and 2003 in the York River (Maki *et al*., 2006). Based on these comparisons, we have concluded that the multifilament nets of the type used in the 1950s have approximately half of the fishing power of monofilament nets used in the 1980s and the current monitoring. Thus, the older data have been adjusted upward (by a factor of 2.16) to make appropriate comparisons with current monitoring results.

Voluntary log books from the 1950s also exist for the James River. The most extensive data are those of Mr. J. C. Smith who fished staked gill nets on the upper James River in 1954-1957, just above the mouth of the Chickahominy River. Current monitoring on the James River is well below this location, complicating direct comparisons with Smith's log books. There are no historic records in department archives for the Rappahannock River.

Using the information presented above and additional analysis, the ASMFC stock assessment subcommittee developed benchmarks for restoration of Virginia's stock of American shad (ASMFC 2007a). These benchmarks were reviewed and accepted by the ASMFC American shad stock assessment peer review panel in 2007 (ASMFC 2007b).

For the York River, a restoration target of 17.44 (the geometric mean of the catch index values observed in 1953-1957) was accepted as an appropriate benchmark to assess the stocks since American shad abundance in the 1980s was insufficient to support the fishery. In the 1950s, shad abundance was higher (estimated at 131,000-218,000 total females annually using data from Nichols and Massmann 1962), and landings were relatively stable in the face of a high fishing rate (50%). Thus, restoring the York River shad stocks to a 1950s level could allow for a sustainable fishery operating at a lower level of exploitation.

For the James River, an interim target of 6.40 (the geometric mean of the catch index values observed in 1980-1993) is available. However, American shad abundance in the 1980s was insufficient to support the fishery. The James River stock is dependent on hatchery inputs and there is strong evidence of persistent recruitment failure of wild stocks.

For the Rappahannock River, an interim restoration target of 1.45 (the geometric mean of the catch index values observed in 1980-1993) is available.

On the York River, the seasonal catch index in 2007 was 5.04. This is an increase from the lowest recorded value of 2.85 in 2006. During the ten years of monitoring, the index has been variable with high values (>12) in 1998 and 2001 and lower values (<9) in other years. The geometric mean of the historical data during the 1980's on the York River is 3.22. The geometric mean of the current monitoring data is higher (7.13), but this mean is lower than the geometric mean of catch indexes from log book records in the 1950s (17.44). In recent years of monitoring (2000-2005), mean age of females has increased as a result of lower proportions of younger fish in the monitoring catch (Figures 21-22). Abundance of juvenile fish in the York River system was low in 1997-2002. The JAI time series suggests recruitment failure in 1999, 2001 and 2002. Catch indices have been trending downward in recent years. In 2006 mean age of females decreased as a result of increased proportions of younger fish in the monitoring catch. The proportion of older fish increased in 2007 and resulted in an increase in mean age of females. Our overall assessment of the York River stock is that it has recovered to a level that is close to its average abundance during the 1980s. However, as noted previously, the stock level was low during that period, and incapable of supporting an active fishery. The stock is currently well below the proposed 1950s target (Figure 26) when abundance of American shad was higher and harvest was apparently sustainable (Nichols and Massmann 1963). As a result, the stock requires continued protection

On the James River, the 2007 index (4.45) is higher than the record low value of 1.74 recorded in 2006, but well below the peak catch index observed in the 1980s (29). Index values in 2000-2005 were higher than those in 1998 and 1999 (2.57 and 2.99, respectively). The geometric mean of the historical data during the 1980's on the James River is 6.40. The geometric mean of the current monitoring data is lower (4.72), but slowly increasing. As noted previously, hatchery cohorts are believed to be recruiting in high proportions to the population, mean age of females has increased in recent years of monitoring (2000-2005), and an increase in the proportion of younger year classes entering the monitoring gear was observed in 2006 and 2007 (Figure 22). Our overall assessment for the James River is that the stock remains at a low level of abundance, but is slowly recovering. The stock requires continued protection and hatchery-based restoration.

On the Rappahannock River, the index in 2007 (2.60) declined with respect to 2003-2006 values and is equivalent to the 2002 value. The 2003-2004 index values were higher than any previous year of monitoring and higher than all years of the historic data. The 1998-2007 geometric mean (3.11) is above the mean of the historical data (1.45) and

the 2003-2004 index values were above the proposed target of 6, however, 2007 values have continued to stay below the proposed target of 6. In recent years of monitoring (2000-2005), mean age of females has increased as a result of reduced catches of younger fish in the monitoring gear (Figure 22). Abundance of juvenile fish in the Rappahannock River was very low in 1999-2001. No juveniles were captured in 2002. However, recruitment has increased in recent years and in 2006 mean age of females decreased due to an increase in younger year classes entering the monitoring gear. As these year classes continue to recruit, the mean age of females has once again increased in 2007. It should be noted that since the catch index for the Rappahannock River is low in the historical data relative to the York and James rivers, there is uncertainty about what an appropriate target level should be for this stock. There is little evidence of severe stock decline in the Rappahannock River, although such a decline was reported in the most recent stock assessment (ASMFC 1999). The present status of the Rappahannock River stock is stable with evidence of increasing abundance. VDGIF personnel began a new hatchery-release program on the upper Rappahannock River recently. The restoration program uses progeny of Potomac River brood stock. The goal of this program is to restore American shad to historical spawning areas that were previously blocked by Embrey Dam.

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Table 1. Summary of sampling dates, total number, and total weight of American shad captured in staked gill nets in the James, York, and Rappahannock Rivers, spring 2007.

Stock	Sampling dates in 2007	Total pre-spawn females	Total males	Total pre-spawn female weight (kg)	Total male weight (kg)	Total fish	Total weight (kg)
James River	2/26-5/6	235	62	332.9	72.1	297	405.1
York River	2/26-/5/6	272	47	400.6	54.7	319	455.3
Rappahannock River	2/27-5/6	127	26	194.5	32.1	153	226.6
Totals		634	135	928.0	158.9	769	1087.0

Table 2. Total length, fork length, and total weight of post-spawning female American shad taken in staked gill nets in the James, York, and Rappahannock Rivers, spring 2007. These individuals were removed from the monitoring data.

River	Date	Specimen number	Total length (mm)	Fork length (mm)	Total weight (g)
James River	4/9/07	12769	561	500	1424.80
	4/20/07	12871	526	471	1574.20
	4/29/07	12975	573	511	1596.50
	4/30/07	12978	518	462	1170.00
Rappahannock River	4/30/2007	12986	560	498	1622.00
	5/6/2007	12992	554	496	1432.00
York River	4/10/07	12796	516	458	1187.90
	4/20/07	12855	498	443	1163.50
	4/20/07	12856	532	473	1420.50
	4/20/07	12857	524	471	1307.70
	4/21/07	12893	499	452	1109.40
	4/21/07	12906	539	483	1329.20
	4/22/07	12926	550	490	1444.80
	4/22/07	12930	560	498	1682.80
	4/22/07	12931	515	461	1188.80
	4/22/07	12933	446	400	715.90
	4/29/07	12966	586	522	1735.20
	4/30/07	12983	533	475	1318.90
	4/30/07	12984	574	508	1627.10
	4/30/07	12985	567	512	1859.20
	5/6/07	12987	474	422	950.50
	5/6/07	12988	476	429	819.10

Table 3. Dates of capture, number, total weight, and catch rates of pre-spawn female American shad taken in staked gill net monitoring on the James River, spring 2007.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
3/4/07	63	7	0.026	10000.9	0.037
3/5/07	64	4	0.015	5221.4	0.019
3/11/07	70	21	0.079	29057.4	0.109
3/12/07	71	25	0.091	34652.5	0.126
3/19/07	78	12	0.044	15836.7	0.058
3/20/07	79	12	0.043	17041.1	0.061
3/25/07	84	29	0.106	43753.7	0.159
3/26/07	85	25	0.090	34692.3	0.125
4/1/07	91	24	0.087	35643.2	0.130
4/2/07	92	24	0.089	34259.0	0.128
4/9/07	99	17	0.062	23523.1	0.086
4/10/07	100	14	0.052	18918.2	0.070
4/20/07	110	7	0.026	9423.7	0.035
4/21/07	111	5	0.018	7649.0	0.028
4/22/07	112	2	0.007	3487.2	0.012
4/23/07	113	4	0.015	5766.1	0.021
4/29/07	119	2	0.007	2600.7	0.009
4/30/07	120	1	0.004	1417.2	0.005
Totals		235		332943.9	

Table 4. Dates of capture, number, total weight, and catch rates of male American shad taken in staked gill net monitoring on the James River, spring 2007.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/27/07	58	1	0.004	1190.5	0.004
3/4/07	63	7	0.026	7855.5	0.029
3/5/07	64	1	0.004	1346.6	0.005
3/11/07	70	9	0.034	9981.3	0.037
3/12/07	71	17	0.062	19773.2	0.072
3/19/07	78	6	0.022	6636.9	0.024
3/20/07	79	5	0.018	5264.0	0.019
3/25/07	84	4	0.015	4702.6	0.017
3/26/07	85	5	0.018	6070.2	0.022
4/1/07	91	1	0.004	1370.0	0.005
4/9/07	99	2	0.007	2202.1	0.008
4/10/07	100	1	0.004	1403.4	0.005
4/21/07	111	2	0.007	2718.9	0.010
4/29/07	119	1	0.004	1601.8	0.006
Totals		62		72117.0	

Table 5. Dates of capture, number, total weight, and catch rates of pre-spawn female American shad taken in staked gill net monitoring on the York River, spring 2007.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/26/07	57	1	0.004	1549.8	0.006
2/27/07	58	1	0.004	1270.7	0.005
3/4/07	63	4	0.015	6104.7	0.022
3/5/07	64	11	0.040	18470.3	0.067
3/11/07	70	4	0.015	6138.7	0.023
3/12/07	71	11	0.040	14965.9	0.055
3/19/07	78	28	0.102	41658.7	0.152
3/20/07	79	45	0.164	66545.1	0.243
3/25/07	84	34	0.124	51691.4	0.188
3/26/07	85	25	0.091	37392.7	0.136
4/1/07	91	12	0.044	17190.5	0.063
4/2/07	92	26	0.091	38294.4	0.134
4/9/07	99	16	0.058	22392.4	0.082
4/10/07	100	18	0.064	25254.3	0.090
4/20/07	110	6	0.022	9429.8	0.034
4/21/07	111	12	0.044	17894.7	0.065
4/22/07	112	7	0.024	8892.1	0.031
4/23/07	113	5	0.017	6860.8	0.024
4/29/07	119	3	0.011	4224.8	0.015
4/30/07	120	2	0.007	2976.8	0.010
5/6/07	126	1	0.004	1441.5	0.005
Totals		272		400640.1	

Table 6. Dates of capture, number, total weight, and catch rates of male American shad taken in staked gill net monitoring on the York River, spring 2007.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
2/27/07	58	1	0.004	1074.0	0.004
3/4/07	63	1	0.004	1209.8	0.004
3/5/07	64	8	0.029	9763.6	0.036
3/11/07	70	3	0.011	4053.9	0.015
3/12/07	71	4	0.015	4712.5	0.017
3/19/07	78	8	0.029	8977.8	0.033
3/20/07	79	8	0.029	9232.1	0.034
3/25/07	84	5	0.018	6693.2	0.024
3/26/07	85	3	0.011	3240.9	0.012
4/1/07	91	1	0.004	1084.5	0.004
4/9/07	99	1	0.004	1237.5	0.005
4/22/07	112	1	0.004	807.5	0.003
4/30/07	120	1	0.004	593.3	0.002
5/6/07	126	2	0.007	2012.6	0.007
Totals		47		54693.2	

Table 7. Dates of capture, number, total weight, and catch rates of pre-spawn female American shad taken in staked gill net monitoring on the Rappahannock River, spring 2007.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
3/4/07	63	1	0.004	2673.2	0.010
3/11/07	70	1	0.004	1629.2	0.006
3/12/07	71	1	0.004	1453.0	0.005
3/19/07	78	2	0.007	3235.5	0.011
3/20/07	79	7	0.026	12687.3	0.048
3/25/07	84	6	0.022	10488.8	0.038
3/26/07	85	8	0.029	12779.8	0.046
4/1/07	91	9	0.032	13704.3	0.049
4/2/07	92	6	0.022	9978.8	0.036
4/9/07	99	10	0.036	14656.7	0.053
4/10/07	100	24	0.086	36103.4	0.130
4/20/07	110	13	0.047	18722.8	0.068
4/21/07	111	12	0.043	16432.7	0.059
4/22/07	112	10	0.036	13686.9	0.049
4/23/07	113	9	0.032	13628.1	0.049
4/29/07	119	7	0.025	10855.4	0.039
5/6/07	126	1	0.004	1792.7	0.006
Totals		127		194508.6	

Table 8. Dates of capture, number, total weight, and catch rates of male American shad taken in staked gill net monitoring on the Rappahannock River, spring 2007.

Date	Day of year	Number	Catch rate (count/m/day)	Total weight (g)	Catch rate (kg/m/day)
3/4/07	63	2	0.007	2490.8	0.009
3/5/07	64	1	0.004	1300.0	0.005
3/11/07	70	1	0.004	1042.7	0.004
3/12/07	71	3	0.011	3685.0	0.013
3/19/07	78	2	0.007	2411.3	0.019
3/20/07	79	5	0.019	6611.0	0.025
3/25/07	84	4	0.014	5142.1	0.018
3/26/07	85	3	0.011	4022.3	0.014
4/2/07	92	1	0.004	1301.7	0.005
4/10/07	100	1	0.004	842.2	0.003
4/20/07	110	1	0.004	1051.9	0.004
4/21/07	111	1	0.004	1247.2	0.004
4/22/07	112	1	0.004	1035.8	0.004
Totals		26		32184.0	

Table 9. Mean total length and mean weight of pre-spawn female American shad captured in staked gill nets in the James, York, and Rappahannock Rivers, spring 2007. The abbreviation NA is "not aged". Age estimates are based on examination of scales following Cating (1953).

River	Year class	Number	Mean total length (mm)	Standard deviation	Mean weight (g)	Standard deviation
James River	2004	4	453.5	20.6	1202.7	144.6
	2003	60	472.9	24.1	1313.8	204.8
	2002	91	481.5	20.4	1401.3	189.2
	2001	37	494.1	25.3	1572.8	253.0
	2000	7	504.1	13.5	1592.0	153.9
	1999	1	562.0		2151.0	
	NA	34	480.7	19.9	1421.5	179.5
York River	2004	4	471.5	21.4	1243.0	123.7
	2003	46	478.5	22.3	1374.9	178.8
	2002	108	481.2	18.8	1411.7	196.6
	2001	48	497.6	18.4	1566.6	190.9
	2000	11	524.2	32.6	1981.5	430.0
	1999	2	558.0	38.2	2212.8	845.1
	1998	1	589.0		2609.4	
	1997	1	582.0		2623.1	
	NA	51	484.4	22.4	1437.3	219.7
Rappahannock River	2004	1	462.0		1151.1	
	2003	21	469.2	12.0	1306.8	125.7
	2002	53	484.7	18.0	1459.4	191.5
	2001	23	496.8	21.3	1633.5	264.5
	2000	10	537.0	29.0	2016.67	418.0
	1998	2	572.0	8.5	2359.65	7.7
	NA	17	491.2	28.8	1535.9	268.0

Table 10. Mean total length and mean weight of male American shad captured in staked gill nets in the James, York, and Rappahannock Rivers, spring 2007. The abbreviation NA is "not aged". Age estimates are based on examination of scales following Cating (1953).

River	Year class	Number	Mean total length (mm)	Standard deviation	Mean weight (g)	Standard deviation
James River	2003	8	458.5	35.3	1179.7	223.2
	2002	18	452.0	14.5	1104.4	88.3
	2001	17	464.4	15.6	1217.8	102.6
	NA	19	458.8	22.7	1163.0	141.0
York River	2004	1	418.0		807.5	
	2003	3	454.0	59.0	1013.8	395.8
	2002	12	453.5	12.9	1140.6	123.2
	2001	11	458.2	17.6	1160.0	133.0
	2000	5	467.4	20.2	1181.4	84.3
	1999	2	481.5	17.7	1379.7	251.9
	NA	13	469.8	16.8	1210.1	163.8
Rappahannock River	2003	4	442.5	13.5	1102.0	203.4
	2002	5	451.4	20.7	1160.1	134.7
	2001	7	474.7	9.4	1356.1	96.9
	2000	1	473.0		1318.3	
	1998	2	496.5	12.0	1467.5	70.6
	NA	7	454.6	14.5	1175.7	130.4

Table 11. Number, total weight, and seasonal catch rates by year class of pre-spawn female American shad captured in staked gill nets in the James, York, and Rappahannock Rivers, spring 2007. The abbreviation NA is "not aged". Age estimates are based on examination of scales following Cating (1953).

River	Year class	Number	Total weight (kg)	Total effort (days)	Seasonal catch rate (count/m/season)	Seasonal catch rate (kg/m/season)
James River	2004	4	4.8	20.0	0.0007	0.0009
	2003	60	78.8	20.0	0.0110	0.0144
	2002	91	127.5	20.0	0.0167	0.0234
	2001	37	58.2	20.0	0.0068	0.0107
	2000	7	11.1	20.0	0.0013	0.0020
	1999	1	2.2	20.0	0.0002	0.0004
	NA	35	50.3	20.0	0.0064	0.0092
Rappahannock River	2004	1	1.2	18.9	0.0002	0.0002
	2003	21	27.4	18.9	0.0040	0.0053
	2002	53	77.3	18.9	0.0102	0.0148
	2001	23	37.6	18.9	0.0044	0.0072
	2000	10	20.2	18.9	0.0019	0.0039
	1998	2	4.7	18.9	0.0004	0.0009
	NA	17	26.1	18.9	0.0033	0.0050
York River	2004	4	5.0	21.2	0.0007	0.0009
	2003	46	63.2	21.2	0.0079	0.0109
	2002	108	152.5	21.2	0.0187	0.0263
	2001	48	75.2	21.2	0.0083	0.0130
	2000	11	21.8	21.2	0.0019	0.0038
	1999	2	4.4	21.2	0.0003	0.0008
	1998	1	2.6	21.2	0.0002	0.0004
	1997	1	2.6	21.2	0.0002	0.0004
	NA	51	73.3	21.2	0.0088	0.0127

Table 12. Number, total weight, and seasonal catch rates by year class of male American shad captured in staked gill nets in the James, York, and Rappahannock Rivers, spring 2007. The abbreviation NA is "not aged". Age estimates are based on examination of scales following Cating (1953).

River	Year class	Number	Total weight (kg)	Total effort (days)	Seasonal catch rate (count/m/season)	Seasonal catch rate (kg/m/season)
James River	2003	8	9.4	20.0	0.0015	0.0017
	2002	18	19.9	20.0	0.0033	0.0036
	2001	17	20.7	20.0	0.0031	0.0038
	NA	19	22.1	20.0	0.0035	0.0040
Rappahannock River	2003	4	4.4	18.9	0.0008	0.0008
	2002	5	5.8	18.9	0.0010	0.0011
	2001	7	9.5	18.9	0.0013	0.0018
	2000	1	1.3	18.9	0.0002	0.0002
	1998	2	2.9	18.9	0.0004	0.0006
	NA	7	8.2	18.9	0.0013	0.0016
York River	2004	1	0.8	21.2	0.0002	0.0001
	2003	3	3.0	21.2	0.0005	0.0005
	2002	12	13.7	21.2	0.0021	0.0024
	2001	11	12.8	21.2	0.0019	0.0022
	2000	5	5.9	21.2	0.0009	0.0010
	1999	2	2.8	21.2	0.0003	0.0005
	NA	13	15.7	21.2	0.0022	0.0027

Table 13. Spawning histories of American shad (combined sexes) collected in spring, 2007 in the York and James Rivers. Table entries are total numbers of fish that were aged (York River, n = 269; James River, n = 247). Ages are based on scale analysis by one reader (B. Watkins). Numbers in bold are virgins in year class. For the James River, the number in parentheses is the number of aged fish out of the total that had hatchery marks on their otoliths (n = 49. The table truncates at age 7 since American shad are mature by that age (Maki et al., 2001).

Age at Maturity

York River Year Class	Age at Capture	3	4	5	6	7
2004	3	**5**	-	-	-	-
2003	4	4	**46**	-	-	-
2002	5	9	52	**60**	-	-
2001	6	1	17	38	**6**	-
2000	7	0	7	7	4	0
1999	8	0	5	2	0	0
1998	9	0	0	3	0	0
1997	10	0	0	2	0	0
1996	11	0	0	1	0	0

Age at Maturity

James River Year Class	Age at Capture	3	4	5	6	7
2004	3	**4(2)**	-	-	-	-
2003	4	6	**63(12)**	-	-	-
2002	5	4(1)	46(8)	**59(11)**	-	-
2001	6	1	20(2)	21(1)	13	0
2000	7	0	2(1)	4	1	0
1999	8	0	8	1	0	0
1998	9	0	0	0	0	0
1997	10	0	0	2	0	0

Table 14. Spawning histories of American shad (combined sexes) collected in spring, 2007 in the Rappahannock River. Table entries are total numbers of fish that were aged (n = 131). Ages are based on scale analysis by one reader (B. Watkins). Numbers in bold are virgins in year class. The table truncates at age 7 since American shad are mature by that age (Maki et al., 2001).

		Age at Maturity				
Rapp. River Year Class	Age at Capture	3	4	5	6	7
2004	3	**1**	-	-	-	-
2003	4	2	**23**	-	-	-
2002	5	0	17	**41**	-	-
2001	6	0	6	20	**4**	-
2000	7	0	3	8	1	0
1999	8	0	0	1	0	0
1998	9	0	0	1	3	0

Table 15. River of origin, age, number of spawns, fork length (FL), total length (TL), total weight (TW), and sex of American shad with hatchery marks (n= 48) taken in staked gill net monitoring on the James River in 2007. A total of 152 American shad were randomly selected and their otoliths scanned for hatchery marks. Data are sorted by spawning history and age. Age estimates are based on scales following Cating (1953). Abbreviations are: NA, not aged

Specimen Number	Sequence	River Origin	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
12674	3,15	James 02	3	0	420	466	1268.8	female
12817	3	James 02-present	3	0	381	425	994.8	female
12288	3	James 02-present	4	0	415	469	1164.1	male
12589	3	James 02-present	4	0	420	467	1200.6	female
12595	3	James 02-present	4	0	429	474	1256.9	female
12604	3	James 02-present	4	0	413	457	1146.9	female
12702	3,15	James 02	4	0	420	474	1289.4	female
12713	3	James 02-present	4	0	443	486	1452.4	female
12778	3	James 02-present	4	0	414	464	1137.4	female
12822	3	James 02-present	4	0	417	469	1337.3	female
12824	3	James 02-present	4	0	404	453	1154.0	female
12867	3	James 02-present	4	0	410	460	1125.4	female
12869	3	James 02-present	4	0	409	453	1221.4	female
12921	3	James 02-present	4	0	440	488	1514.9	female
12285	3	James 02-present	5	0	429	478	1365.9	female
12322	3	James 02-present	5	0	444	497	1590.6	female
12344	3	James 02-present	5	0	424	476	1228.0	female
12366	3	James 02-present	5	0	414	462	1155.4	female
12436	3	James 02- present	5	0	420	473	1243.9	female
12438	3	James 02-present	5	0	457	517	1774.0	female
12509	3	James 02-present	5	0	431	472	1379.8	female
12519	3	James 02-present	5	0	450	503	1529.5	female
12701	3	James 02-present	5	0	401	452	1148.4	female
12709	3	James 02-present	5	0	433	486	1519.1	female
12710	3	James 02-present	5	0	384	432	1093.5	female
12339	3	James 02-present	5	1	399	447	1082.9	male
12360	3	James 02-present	5	1	439	486	1549.3	female
12365	3,15	James 02	5	1	408	458	1119.7	male
12496	3	James 02-present	5	1	463	516	1615.4	female
12596	3	James 02-present	5	1	426	476	1158.1	female
12601	3	James 02-present	5	1	410	462	1169.6	male
12670	3	James 02-present	5	1	440	500	1555.2	female
12772	3	James 02-present	5	1	434	487	1529.0	female

Specimen Number	Sequence	River Origin	Age	Spawns	FL (mm)	TL (mm)	TW (g)	Sex
12337	3	James 02-present	5	2	435	480	1411.9	female
12594	3	James 02-present	6	1	433	482	1462.8	female
12326	3	James 02-present	6	2	415	471	1275.2	male
12334	3	James 02-present	6	2	408	455	1272.1	male
12278	3	James 02-present	7	3	444	495	1685.8	female
12975	3	James 02-present	10	5	511	573	1596.5	female
12214	3	James 02-present	NA	NA	388	439	1007.5	male
12268	3	James 02-present	NA	NA	397	444	972.8	male
12324	3	James 02-present	NA	NA	456	507	1568.8	female
12348	3	James 02-present	NA	NA	410	458	1097.8	male
12425	3	James 02-present	NA	NA	394	442	1100.2	male
12510	3	James 02-present	NA	NA	418	464	1232.5	male
12682	3	James 02-present	NA	NA	428	480	1450.0	female
12773	3	James 02-present	NA	NA	433	487	1411.7	female
12780	3	James 02-present	NA	NA	429	491	1473.2	female

Table 16. Total numbers in nine year classes of hatchery-marked American shad taken in staked gill nets in the James River, 1998-2007. Ages are based on examination of scales. Hatchery production data courtesy of the Virginia Department of Game and Inland Fisheries (D. Fowler). Abbreviation: NA, not aged.

Hatchery Year Class	Hatchery Production (millions)	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	Total	% Total
1992	0.05		1									1	0.1
1993	0.5	7	2	1								10	1.4
1994	1.6	7	3	9			1					20	2.8
1995	5.3			59	9	8	4	3				83	11.8
1996	5.8			53	62	43	10	4	1			173	24.6
1997	5.9			2	27	78	57	5	4		1	174	24.8
1998	10					13	52	17	13			95	13.5
1999	7.3						14	29	7			50	7.1
2000	8.9						1	5	9		1	16	2.3
2001	9.3								3	4	3	10	1.4
2002	8.4									4	20	24	3.4
2003	8.7										12	12	1.7
2004	6.6										2	2	0.3
2005	6.0												
2006	7.0												
2007	6.5												
NA	--					12	3	5	3	1	9	33	4.7
Total	97.85	14	6	124	98	154	142	68	40	9	48	703	100.0

Table 17. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2007) on the James and Rappahannock rivers. The index is the geometric mean catch per haul. Abbreviations are: SD, standard deviation; N, number of seine hauls.

Year	James River	SD	N	Rappahannock River	SD	N
1980	0		11	0		4
1981	0		12	0		4
1982	0		12	0.88	1.081	16
1983	0		8	0.32	0.549	4
1984	0.09	0.245	8	0.41	0.693	4
1985	0		16	0		8
1986	0		12	0.06	0.200	12
1987	0		16	0.12	0.315	16
1988	0		16	0		20
1989	0		16	0.52	0.894	25
1990	0		16	0.03	0.131	28
1991	0		20	0		31
1992	0		20	0		35
1993	0		20	0.13	0.441	31
1994	0		20	0.05	0.220	34
1995	0		20	0		33
1996	0		20	0.35	0.655	32
1997	0		20	0.16	0.444	35
1998	0.04	0.155	20	0.12	0.341	29
1999	0		20	0.02	0.117	35
2000	0		20	0.03	0.188	34
2001	0		20	0.04	0.163	35
2002	0		20	0		35
2003	0.04	0.155	20	0.59	0.659	28
2004	0.04	0.155	20	0.70	0.901	35
2005	0	0	20	0.18	0.592	33
2006	0.11	0.254	20	0.08	0.245	34
2007	0.04	0.155	20	0.16	0.354	35

Table 18. Indexes of abundance of juvenile American shad collected in beach seine surveys (1980-2007) on the Mattaponi, Pamunkey, and York rivers. The index is the geometric mean catch per haul. Abbreviations are: SD, standard deviation; N, number of seine hauls.

Year	Mattaponi River	SD	N	Pamunkey River	SD	N	York River	SD	N
1980	1.75	1.059	21	0.51	0.825	9	1.13	1.000	33
1981	0.35	0.564	16	0.33	0.588	16	0.34	0.567	32
1982	13.03	1.256	16	0.51	0.543	12	4.40	1.502	28
1983	2.80	0.954	16	0.63	0.775	12	1.65	0.965	88
1984	16.97	1.125	16	0.06	0.200	12	4.34	1.660	28
1985	7.21	1.369	32	0.56	0.631	24	3.03	1.381	56
1986	0.87	0.902	24	0.00		18	0.43	0.744	42
1987	0.17	0.461	24	0.00		18	0.09	0.354	42
1988	0.00		40	0.00		24	0.00		64
1989	0.41	0.631	40	0.00		32	0.20	0.487	34
1990	0.18	0.473	40	0.00		32	0.09	0.351	76
1991	0.04	0.253	50	0.02	0.111	39	0.03	0.197	94
1992	0.00		39	0.00		32	0.00		75
1993	0.18	0.489	50	0.00		39	0.09	0.365	94
1994	1.69	1.142	50	0.15	0.435	39	0.80	0.977	94
1995	0.03	0.137	50	0.00		40	0.01	0.100	95
1996	14.61	1.352	49	1.97	1.294	39	5.79	1.572	93
1997	2.23	1.107	50	0.36	0.672	40	1.11	1.017	95
1998	2.11	1.206	48	0.06	0.356	38	0.86	1.052	91
1999	0.14	0.407	47	0.00		38	0.07	0.303	88
2000	5.56	1.33	39	0.06	0.23	31	1.76	1.338	74
2001	0.52	0.665	48	0.11	0.296	40	0.30	0.541	94
2002	0.17	0.408	48	0.02	0.11	40	0.09	0.308	93
2003	8.55	1.315	50	13.11	1.057	39	9.04	1.294	94
2004	7.40	1.389	47	0.05	0.208	38	2.10	1.454	90
2005	1.66	1.351	50	0.02	0.110	40	0.68	1.091	95
2006	0.29	0.554	48	0.00	0.00	37	0.14	0.422	90
2007	0.24	0.487	47	0.00	0.00	36	0.12	0.370	88

Table 19. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the James River, 2007.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/26/07	109	27	136	2	138
2/27/07	231	27	258	7	265
3/4/07	146	68	214	146	360
3/5/07	147	52	199	532	731
3/11/07	216	63	279	106	385
3/12/07	330	90	420	139	559
3/19/07	348	70	418	135	553
3/20/07	337	92	429	160	589
3/25/07	50	28	78	130	208
3/26/07	47	35	82	224	306
4/1/07	38	103	141	640	781
4/2/07	18	62	80	516	596
4/9/07	29	18	47	579	626
4/10/07	24	12	36	402	438
4/20/07	24	32	56	117	173
4/21/07	14	15	29	103	132
4/22/07	17	28	45	100	145
4/23/07	29	34	63	125	188
4/29/07	11	41	52	649	701
4/30/07	10	24	34	395	429
5/6/07	18	43	61	345	406
Totals	2,193	964	3,157	5,552	8,709

Table 20. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the York River, 2007.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/26/07	206	14	220	245	465
2/27/07	219	16	235	151	386
3/4/07	64	16	80	20	100
3/5/07	176	53	229	199	428
3/11/07	104	18	122	296	418
3/12/07	77	40	117	853	970
3/19/07	73	45	118	455	573
3/20/07	80	43	123	242	365
3/25/07	16	14	30	514	544
3/26/07	14	11	25	628	653
4/1/07	11	17	28	716	744
4/2/07	8	16	24	712	736
4/9/07	17	27	44	493	537
4/10/07	12	9	21	679	700
4/20/07	15	22	37	281	318
4/21/07	10	26	36	227	263
4/22/07	4	4	8	220	228
4/23/07	3	9	12	420	432
4/29/07	3	22	25	466	491
4/30/07	7	8	15	432	447
5/6/07	4	24	28	171	199
Totals	1,123	454	1,577	8,420	9,997

Table 21. Daily numbers and seasonal totals of live or dead striped bass (SB) and other species captured by staked gill net in the Rappahannock River, 2007.

Date	Live SB	Dead SB	Total SB	Other species	Total
2/26/07	158	15	173	305	478
2/27/07	104	12	116	278	394
3/4/07	77	52	129	618	747
3/5/07	101	39	140	180	320
3/11/07	48	6	54	208	262
3/12/07	61	12	73	187	260
3/19/07	168	109	277	210	487
3/20/07	69	76	145	208	353
3/25/07	167	164	331	140	471
3/26/07	72	127	199	453	652
4/1/07	8	25	33	568	601
4/2/07	11	21	32	701	733
4/9/07	25	26	51	358	409
4/10/07	27	20	47	285	332
4/20/07	3	2	5	149	154
4/21/07	3	2	5	132	137
4/22/07	4	2	6	237	243
4/23/07	6	0	6	251	257
4/29/07	7	13	20	442	462
4/30/07	45	39	84	458	542
5/6/07	2	5	7	365	372
Totals	1,166	767	1,933	6,733	8,666

Table 22. Summary of historical catch and effort data of American shad by staked gill nets in the Rappahannock River, Virginia. Historical data are taken from the voluntary log books of Mr. M. Delano, Urbanna, Virginia.

Year	Effort (10^3 m/yr)	Duration of run (days)	Highest catch rate (female kg/m/day)	Mean catch rate (female kg/m/day)	Area under the catch curve
1980	43.4	35	0.121	0.036	1.79
1981	112.1	57	0.032	0.011	1.89
1982	82.3	51	0.046	0.009	1.68
1983	106.7	59	0.093	0.031	0.59
1984	30.5	48	0.139	0.033	0.60
1985	77.2	60	0.136	0.029	1.83
1986	34.9	43	0.155	0.039	2.18
1987	23.3	37	0.090	0.023	0.97
1988	23.2	53	0.073	0.025	1.25
1989	16.2	44	0.856	0.123	6.19
1990	41.3	55	0.092	0.023	1.31
1991	25.9	54	0.129	0.022	1.13
1992	8.6	51	0.299	0.044	1.44
Geometric mean					**1.45**

Table 23. Summary of recent catch and effort data of American shad by staked gill nets in the Rappahannock River, Virginia.

Year	Effort (10^3 m/yr)	Duration of run (days)	Highest catch rate (female kg/m/day)	Mean catch rate (female kg/m/day)	Area under the catch curve
1998	3.8	----	0.053	0.020	1.46
1999	5.7	42	0.055	0.026	1.30
2000	6.6	73	0.141	0.042	1.75
2001	6.6	72	0.167	0.070	5.77
2002	5.4	57	0.110	0.028	3.08
2003	7.2	72	0.311	0.094	7.10
2004	5.2	65	0.232	0.107	7.06
2005	5.5	65	0.164	0.054	3.69
2006	6.7	75	0.088	0.037	3.01
2007	5.2	64	0.130	0.042	**2.60**
Geometric mean					**3.11**

Table 24. Historical catch and effort data of American shad captured by staked gill nets in the York River, Virginia. 1950's historical data are taken from the voluntary log books of Malvin Green, Aberdeen Creek,Virginia. The data were originally recorded as numbers of female shad per meter of net per day and were converted to weight (kg) of female shad per meter of net per day, assuming an average female weight of 1.45kg. Catch rates were multiplied by 2.16 to adjust for the lower fishing power of multifilament nets compared to current monofilament nets. 1980's historical data are taken from the voluntary log books of Mr. R. Kellum, Achilles, Virginia.

Year	Effort (10^3m/yr)	Duration of run (days)	Highest catch rate (female kg/m/day)	Mean catch rate (female kg/m/day)	Area under the catch curve
1953	36.0	56	0.549	0.443	14.88
1954	45.5	54	0.699	0.434	14.04
1955	40.1	55	0.310	0.270	8.70
1956	68.8	85	1.201	0.663	33.95
1957	56.2	65	0.955	0.667	26.14
Geometric mean					**17.44**
1980	79.4	44	0.556	0.268	10.15
1981	114.7	51	0.259	0.121	4.35
1982	86.4	44	0.326	0.101	5.31
1983	121.3	40	0.212	0.066	3.06
1984	171.4	48	0.548	0.139	8.21
1985	205.4	49	0.227	0.091	4.61
1986	185.2	38	0.145	0.055	2.17
1987	152.9	37	0.088	0.039	1.78
1988	126.2	40	0.134	0.028	1.34
1989	146.3	55	0.397	0.131	4.92
1990	106.9	38	0.951	0.037	1.31
1991	77.8	40	0.111	0.062	2.72
1992	60.8	41	0.079	0.041	1.60
Geometric mean					**3.22**

Table 25. Summary of recent catch and effort data of American shad by staked gill nets in the York River, Virginia.

Year	Effort (10^3m/yr)	Duration of run (days)	Highest catch rate (female kg/m/day)	Mean catch rate (female kg/m/day)	Area under the catch curve
1998	5.7	78	1.080	0.190	14.71
1999	6.3	65	0.209	0.075	5.42
2000	6.7	76	0.276	0.086	7.52
2001	6.3	79	0.627	0.163	12.97
2002	6.7	70	0.306	0.073	7.47
2003	6.0	70	0.390	0.111	8.98
2004	4.9	65	0.448	0.157	9.72
2005	5.5	73	0.135	0.063	4.64
2006	5.5	62	0.146	0.042	2.85
2007	5.8	70	0.243	0.069	**5.04**
Geometric mean					**7.13**

Table 26. Summary of historical catch and effort data of American shad by staked gill nets in the James River, Virginia. Historical data are taken from the voluntary log books of the Brown family, Rescue, Virginia.

Year	Effort (10^3m/yr)	Duration of run (days)	Highest catch rate (female kg/m/day)	Mean catch rate (female kg/m/day)	Area under the catch curve
1980	20.5	41	2.239	0.699	29.20
1981	67.7	41	0.547	0.130	5.20
1982	49.3	35	0.331	0.115	4.20
1983	94.0	57	1.274	0.297	16.50
1984	89.7	50	0.897	0.036	19.30
1985	91.3	45	0.295	0.103	4.90
1986	31.5	26	1.289	0.152	6.10
1987	30.1	30	0.352	0.085	2.70
1988	19.1	20	0.487	0.193	9.30
1989	31.5	30	0.331	0.176	6.40
1990	29.7	25	0.184	0.079	2.10
1991	28.3	40	0.138	0.062	1.90
1992	59.8	50	0.562	0.232	7.70
Geometric mean					**6.40**

Table 27. Summary of recent catch and effort data of American shad by staked gill nets in the James River, Virginia

Year	Effort (10^3m/yr)	Duration of run (days)	Highest catch rate (female kg/m/day)	Mean catch rate (female kg/m/day)	Area under the catch curve
1998	3.8	50	0.198	0.051	2.57
1999	6.0	66	0.183	0.042	2.99
2000	7.2	70	0.279	0.086	6.61
2001	6.8	78	0.285	0.064	5.01
2002	6.5	71	0.205	0.054	5.62
2003	6.6	79	0.284	0.112	9.34
2004	6.0	78	0.234	0.090	7.41
2005	5.3	72	0.357	0.099	7.16
2006	4.6	54	0.078	0.032	1.74
2007	5.5	58	0.159	0.068	**4.45**
Geometric mean					**4.72**

Figure 1. **Commercial landings of American shad along the Atlantic coast and in Virginia since 1950. Data source: National Marine Fisheries Service, Fisheries Statistics and Economics Division.**

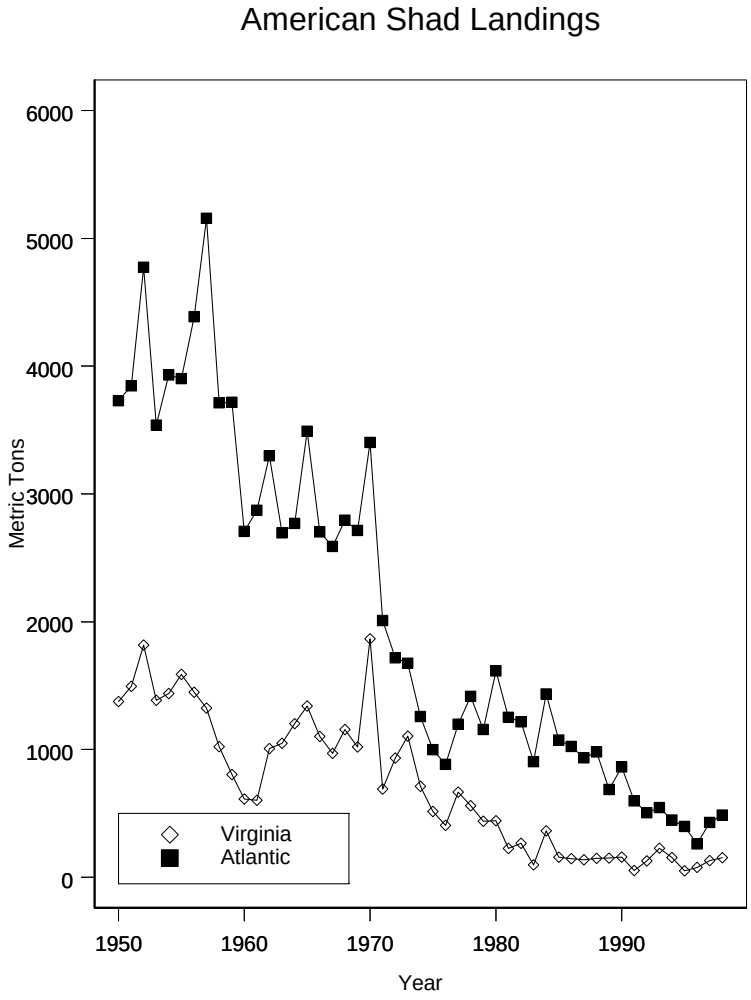


Figure 2. Number and location of staked gill nets on the James River in 1983.

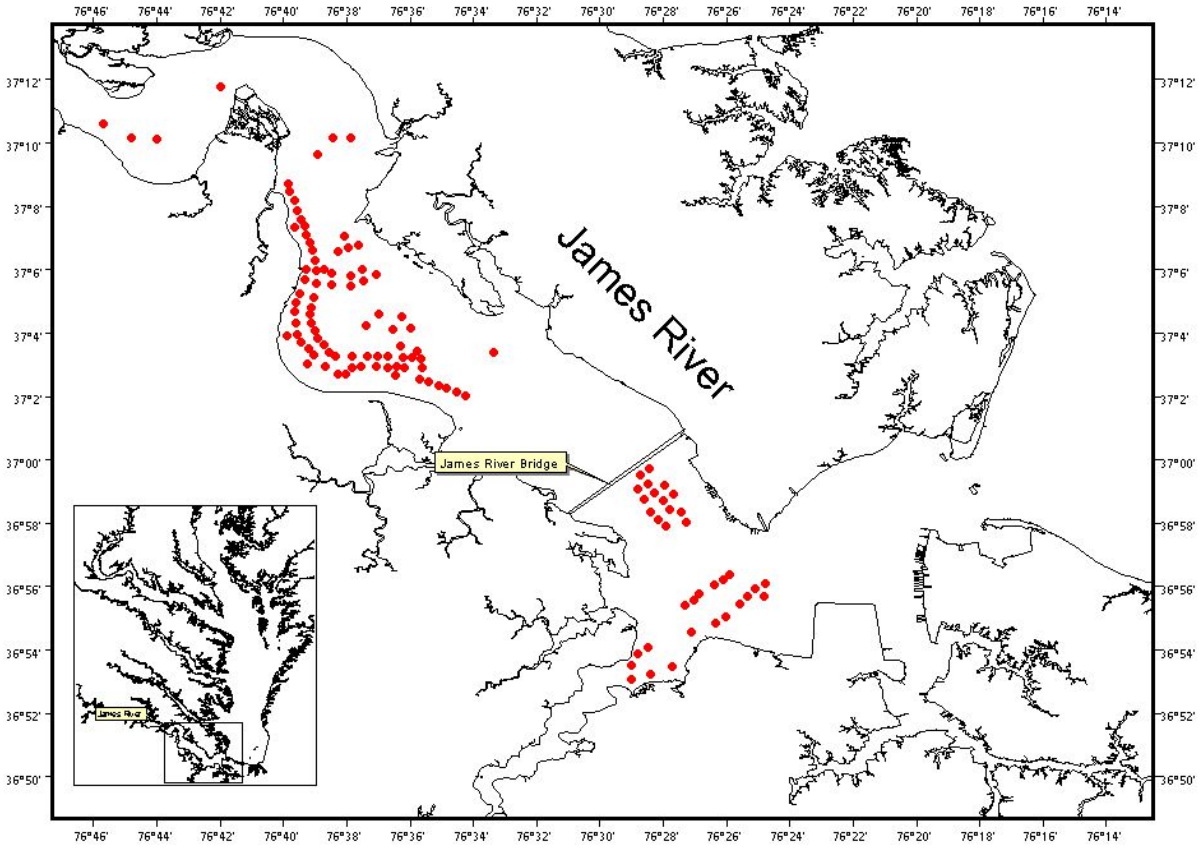


Figure 3. Number and location of staked gill nets on the York River in 1983.

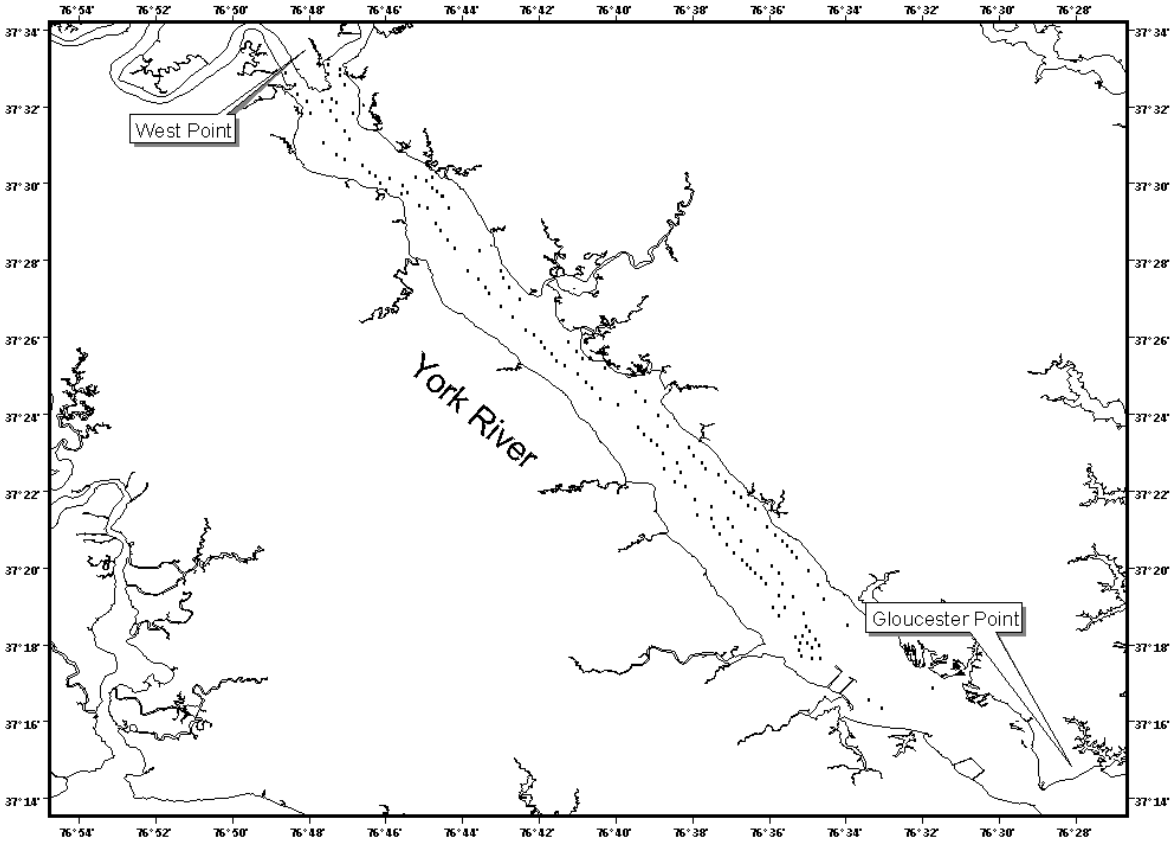


Figure 4. Number and location of staked gill nets on the Rappahannock River in 1983.

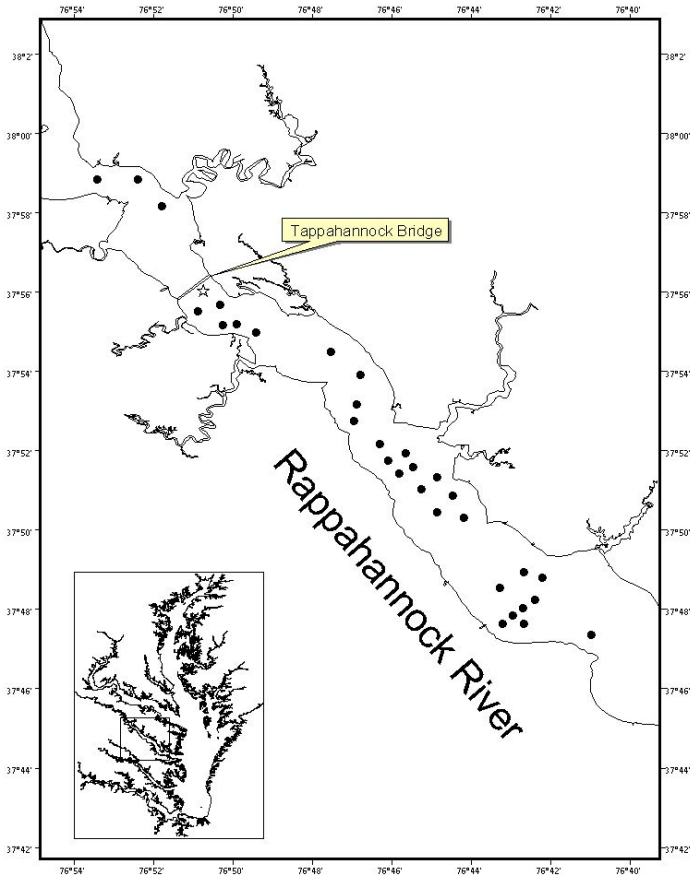


Figure 5. Location of the staked gill net fished by Mr. Marc Brown on the James River. The length of the net (273 m) is not to scale.

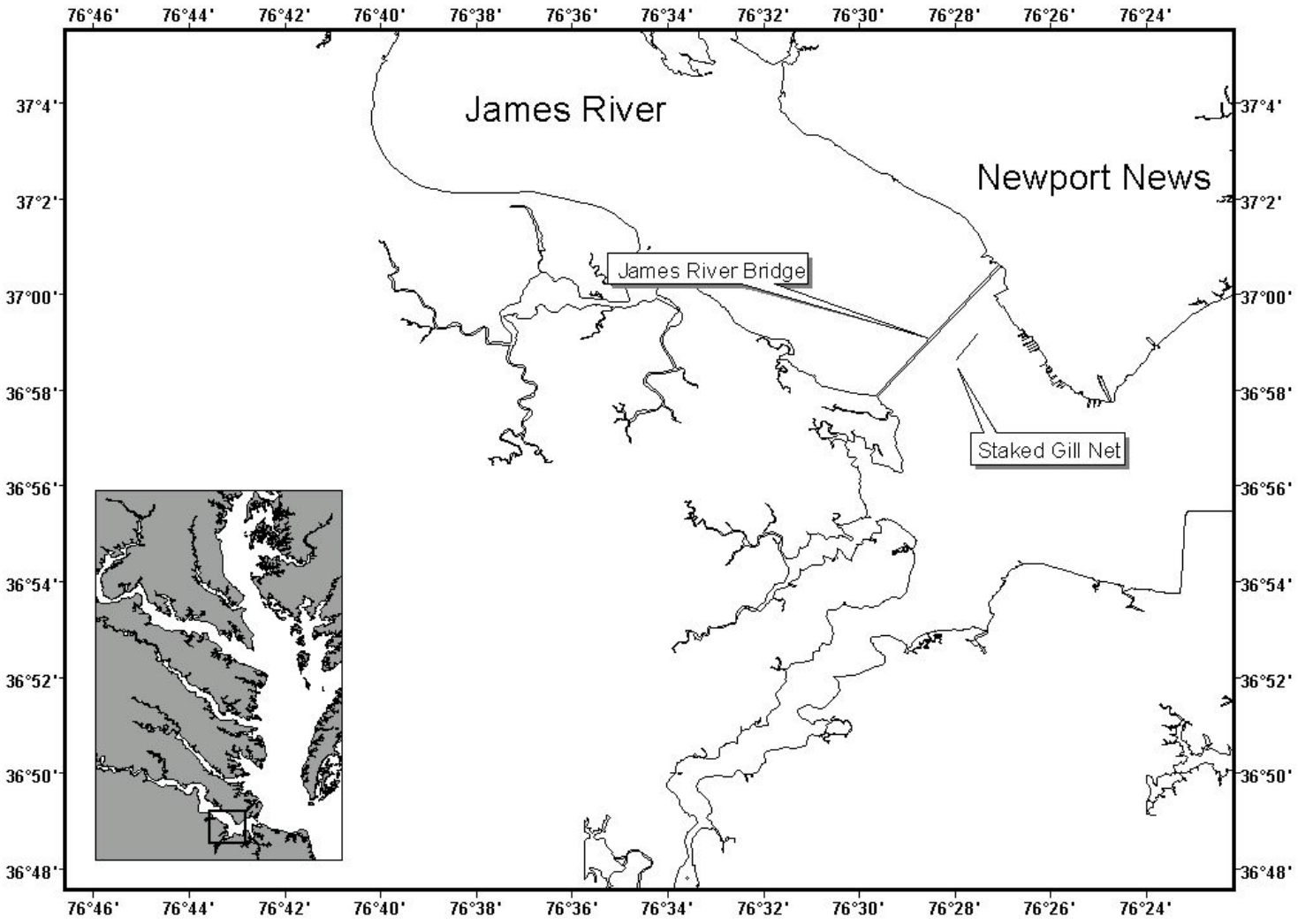


Figure 6. Location of the staked gill net fished by Mr. Raymond Kellum on the York River. The length of the net (273 m) is not to scale.

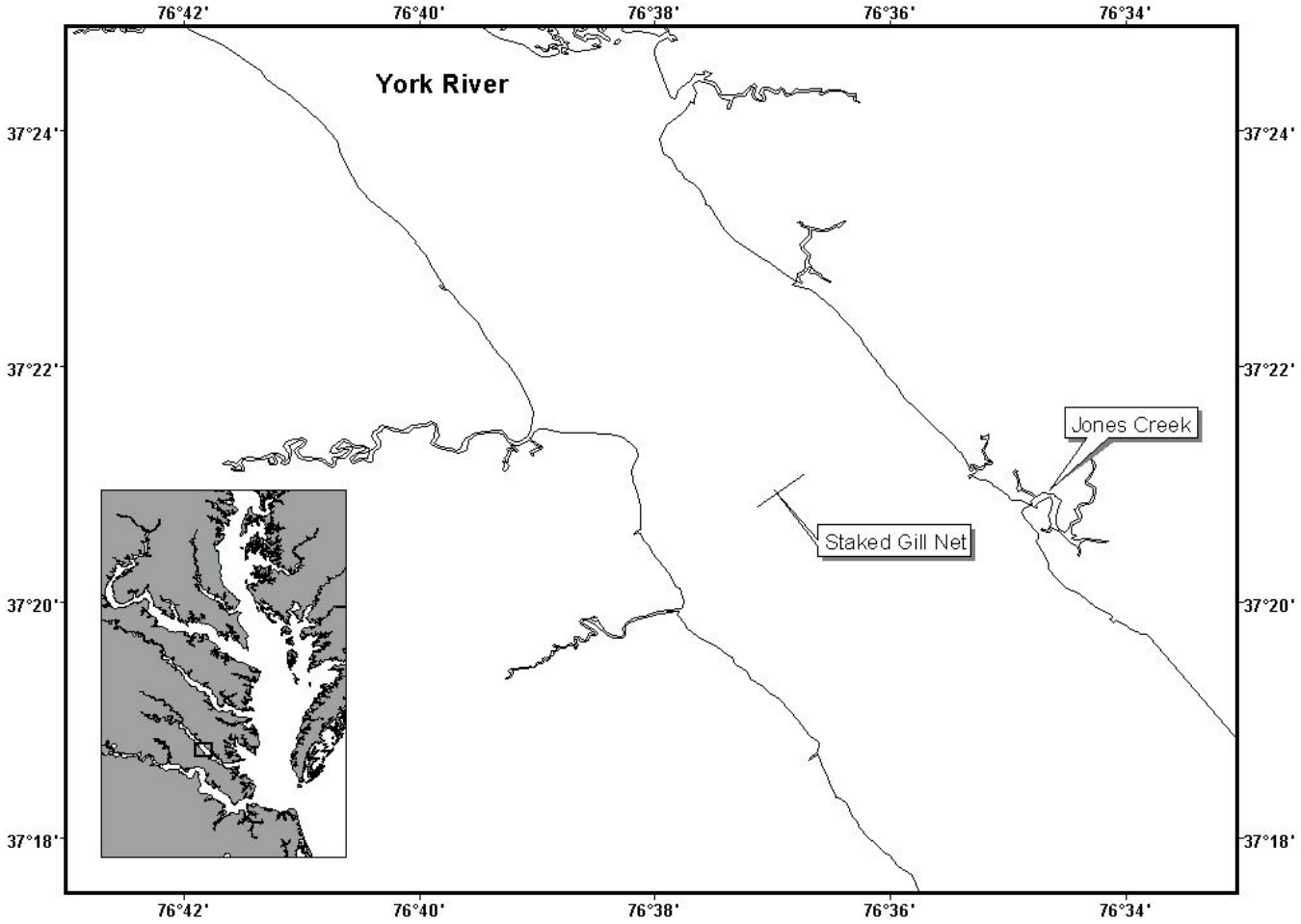


Figure 7. Location of the staked gill net fished by Mr. Jamie Sanders on the Rappahannock River. The length of the net (276 m) is not to scale.

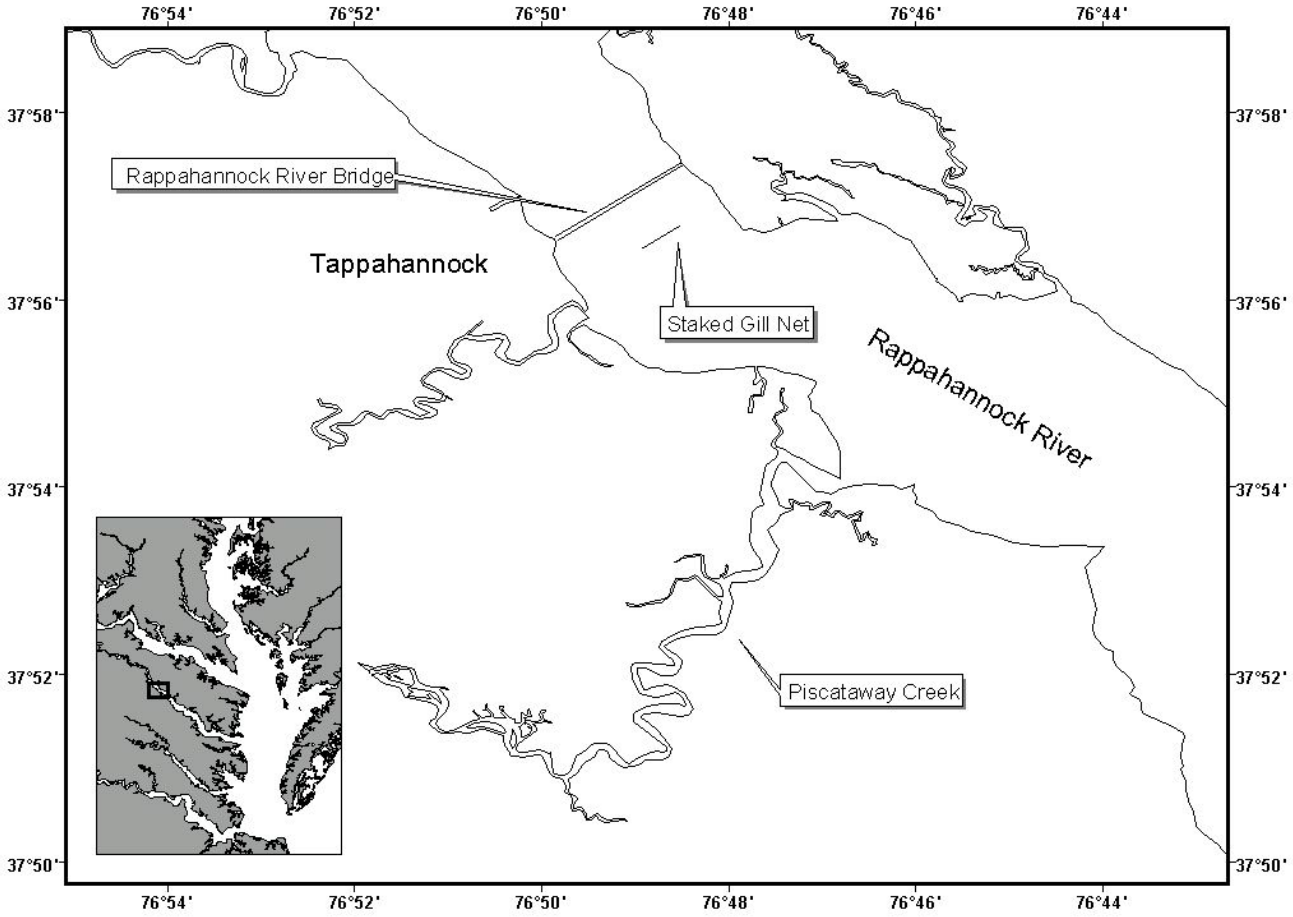


Figure 8. **Catch rates and total numbers of female American shad taken by staked gill nets in the James River, spring 2007.**

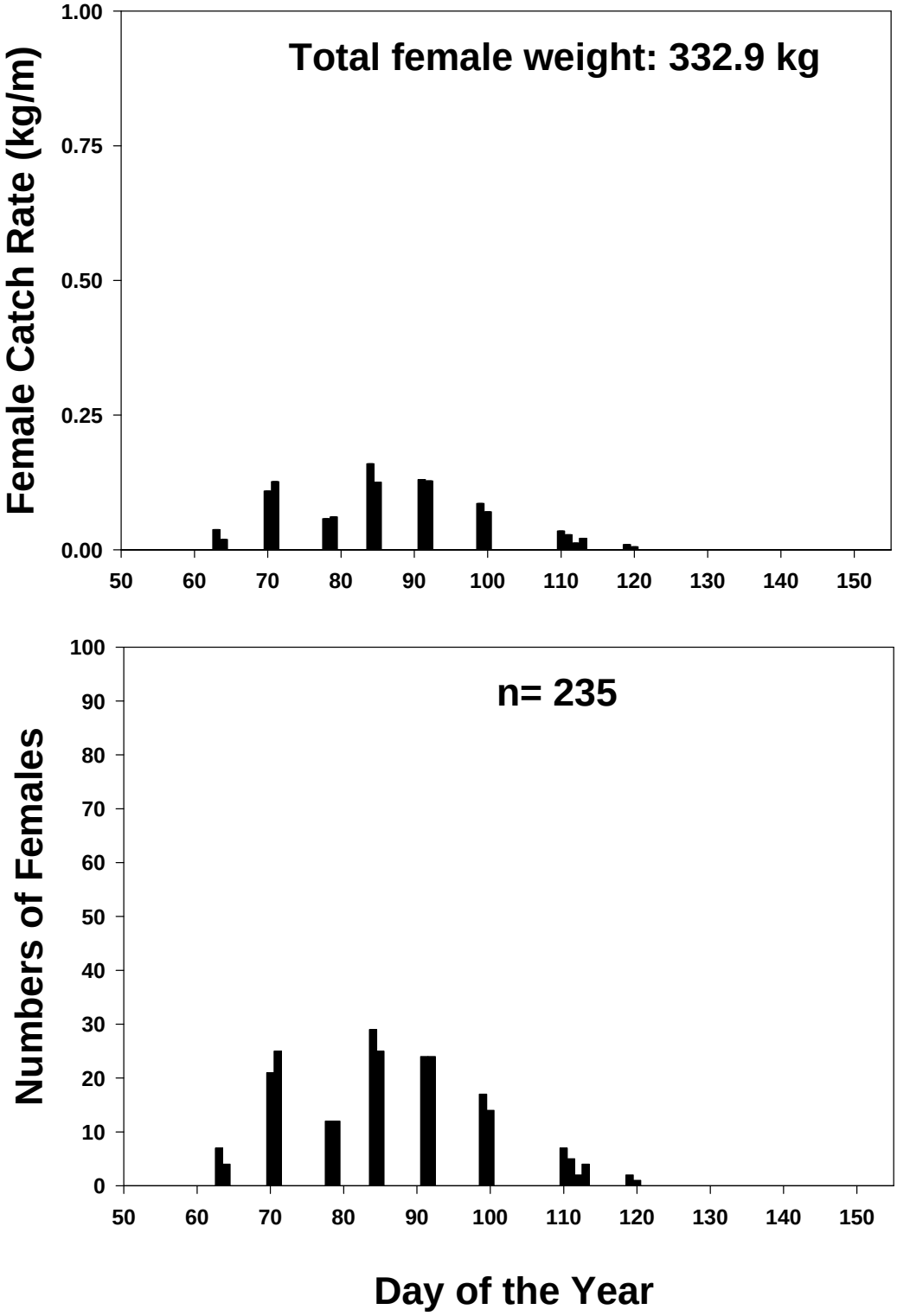


Figure 9. **Catch rates and total numbers of female American shad taken by staked gill nets in the York River, spring 2007.**

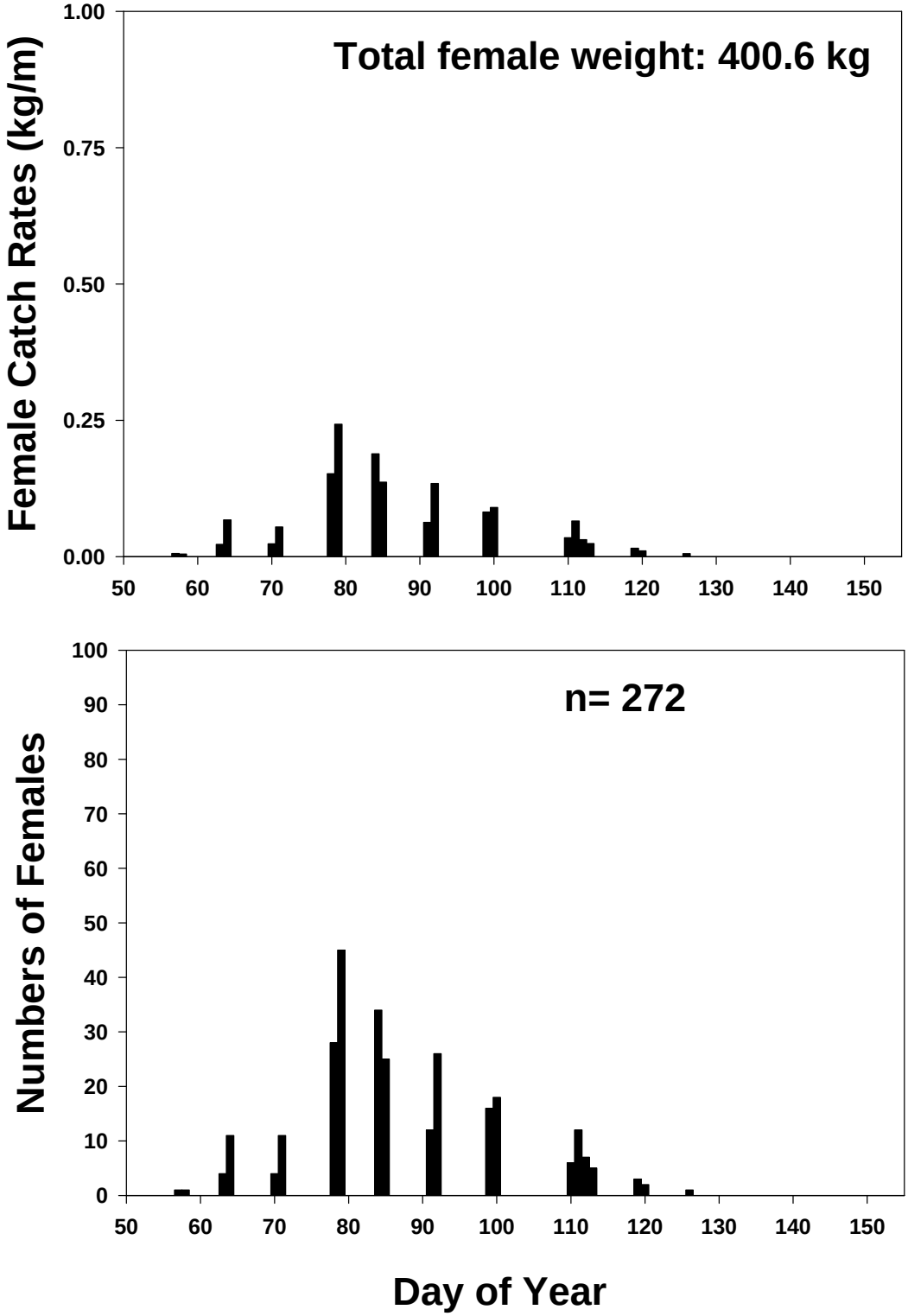


Figure 10. Catch rates and total numbers of female American shad taken by staked gill nets in the Rappahannock River, spring 2007.

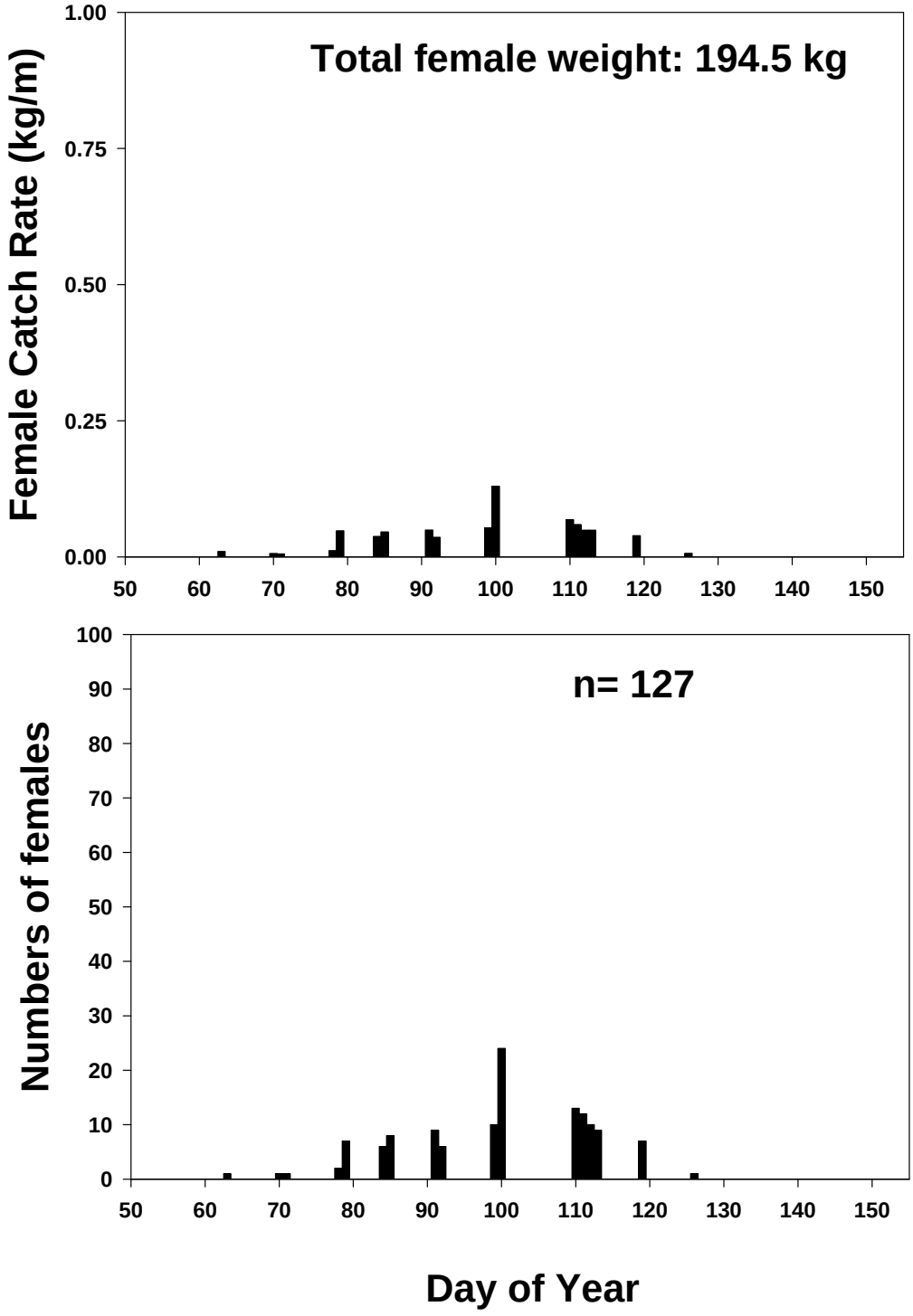


Figure 11. Catch rates and total numbers of male American shad taken by staked gill nets in the James River, spring 2007.

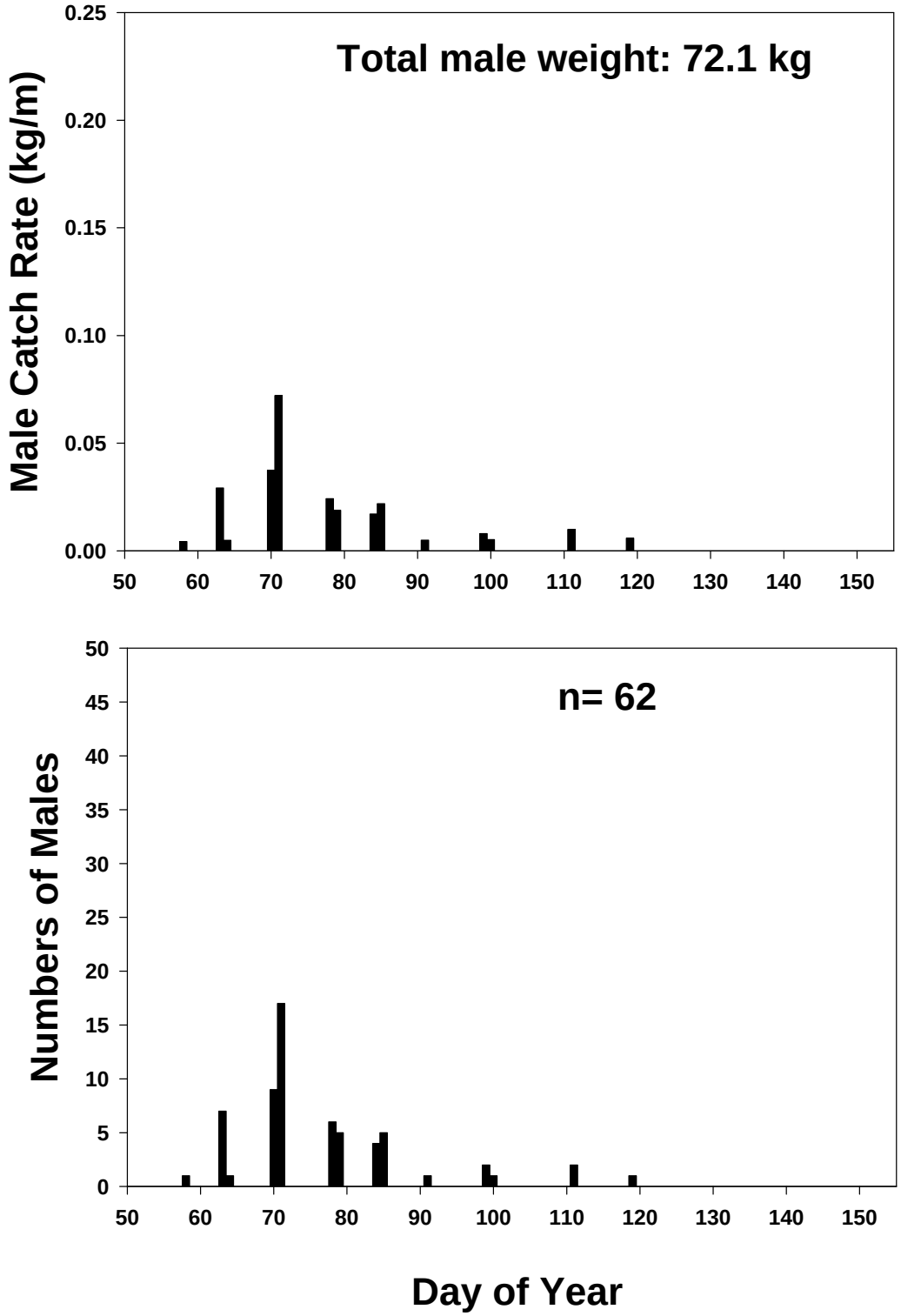


Figure 12. Catch rates and total numbers of male American shad taken by staked gill nets in the York River, spring 2007.

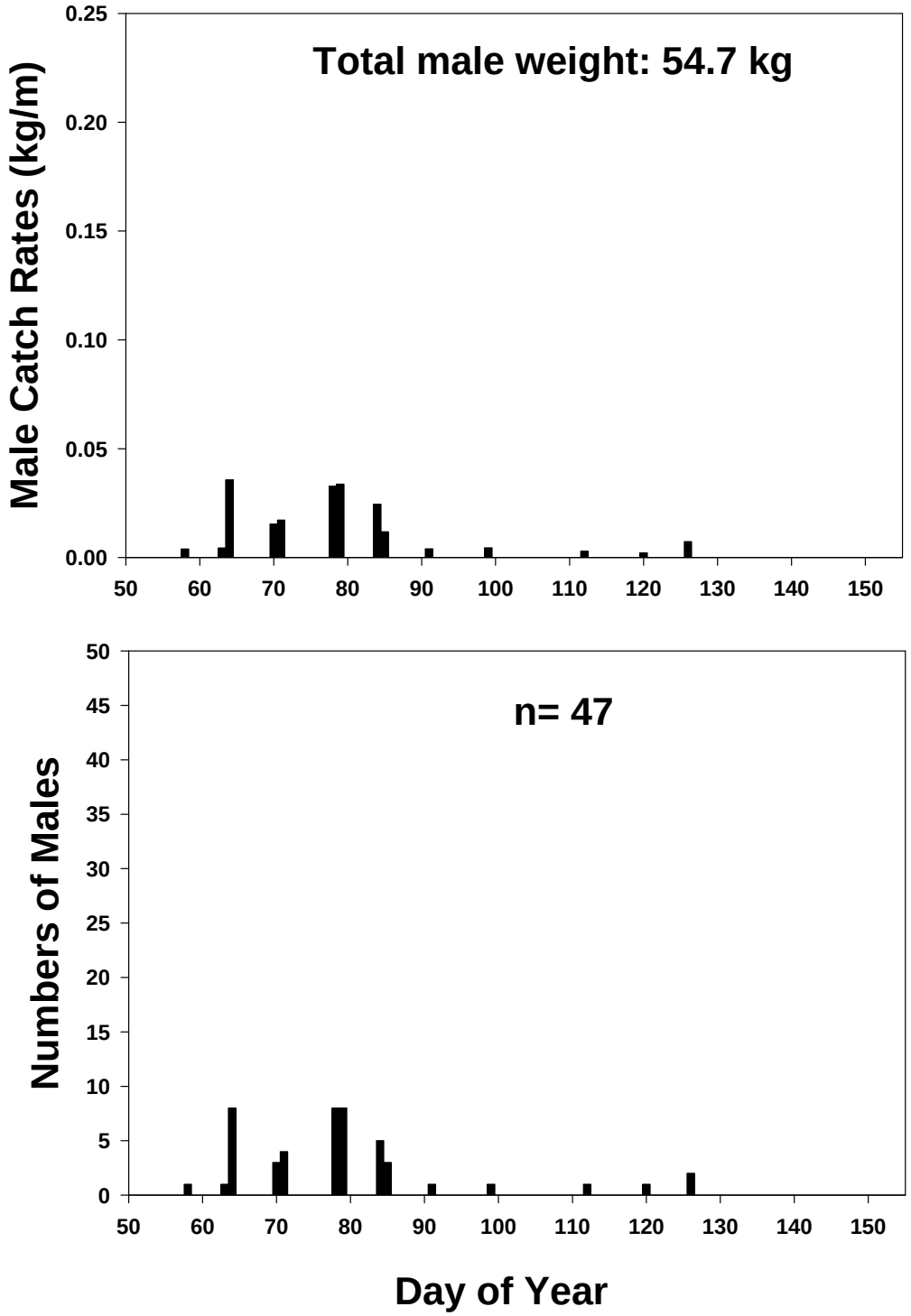


Figure 13. Catch rates and total numbers of male American shad taken by staked gill nets in the Rappahannock River, spring 2007.

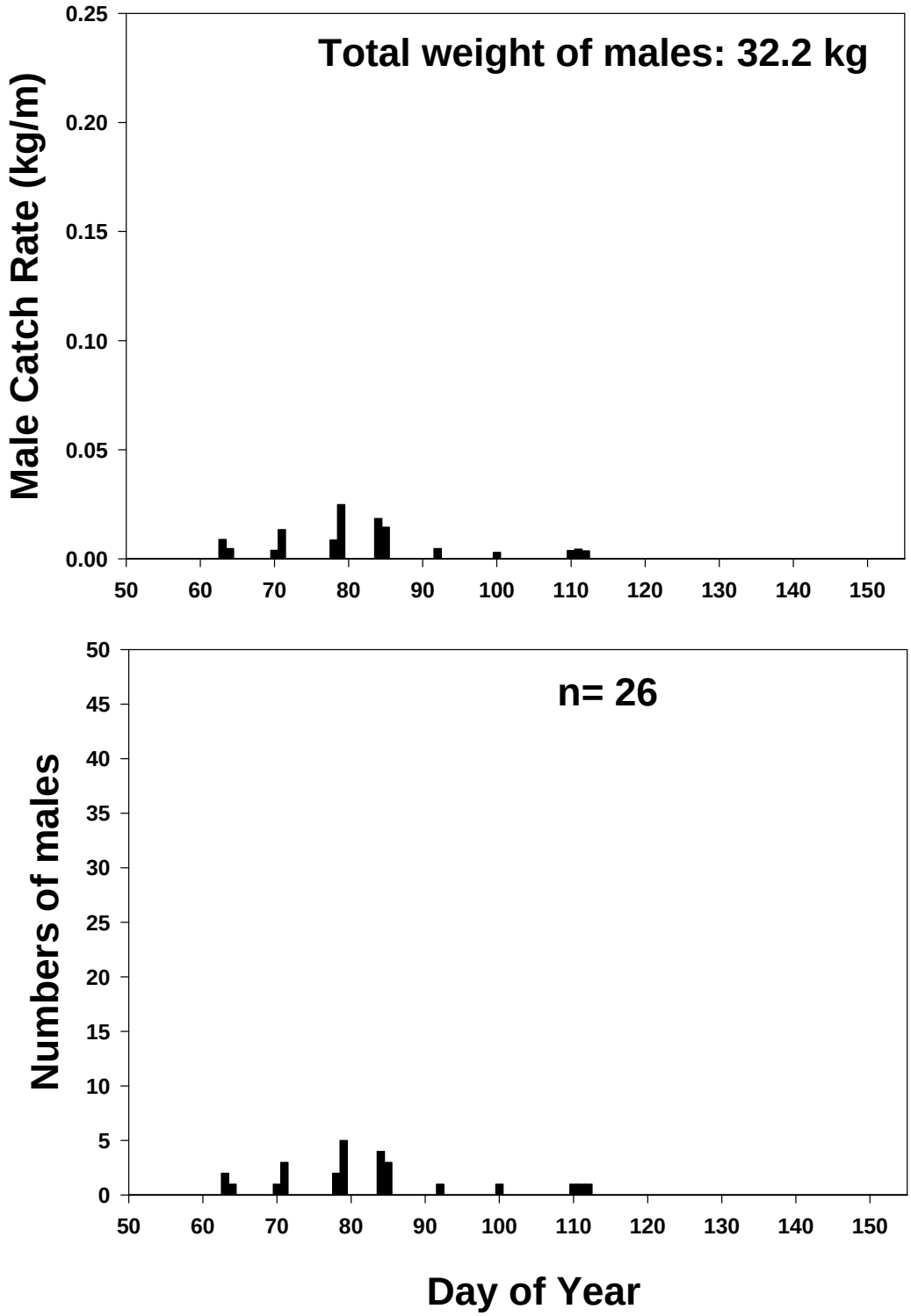
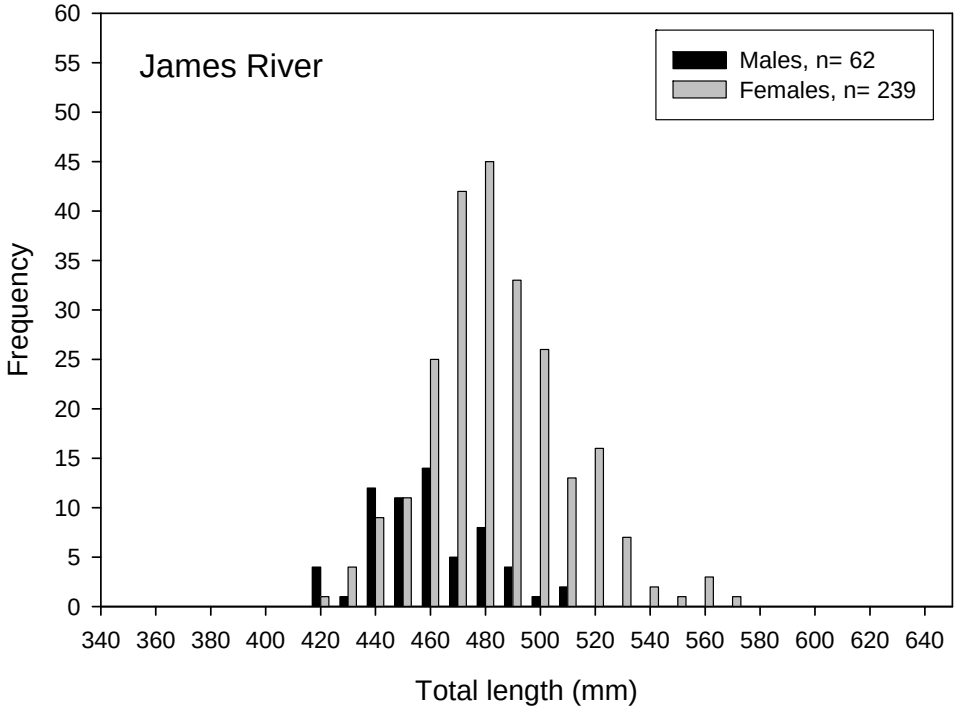


Figure 14. Total length (mm) frequency distributions for American shad captured in staked gill nets on the James and York rivers, spring 2007.



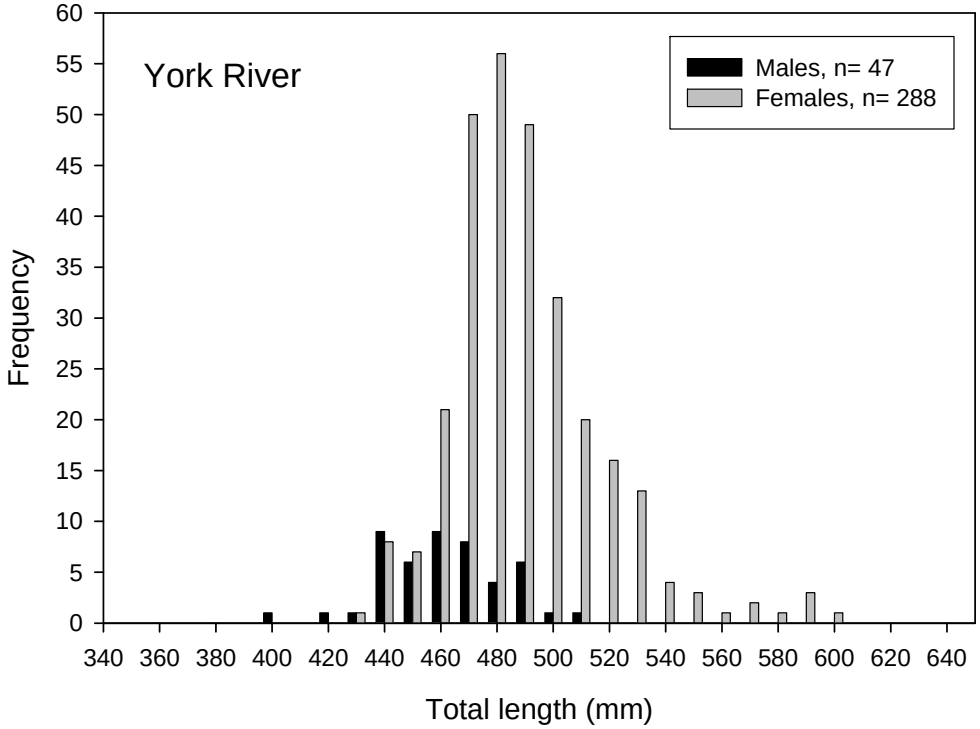


Figure 15. Total length (mm) frequency distributions for American shad captured in staked gill nets on the Rappahannock River, spring 2007.

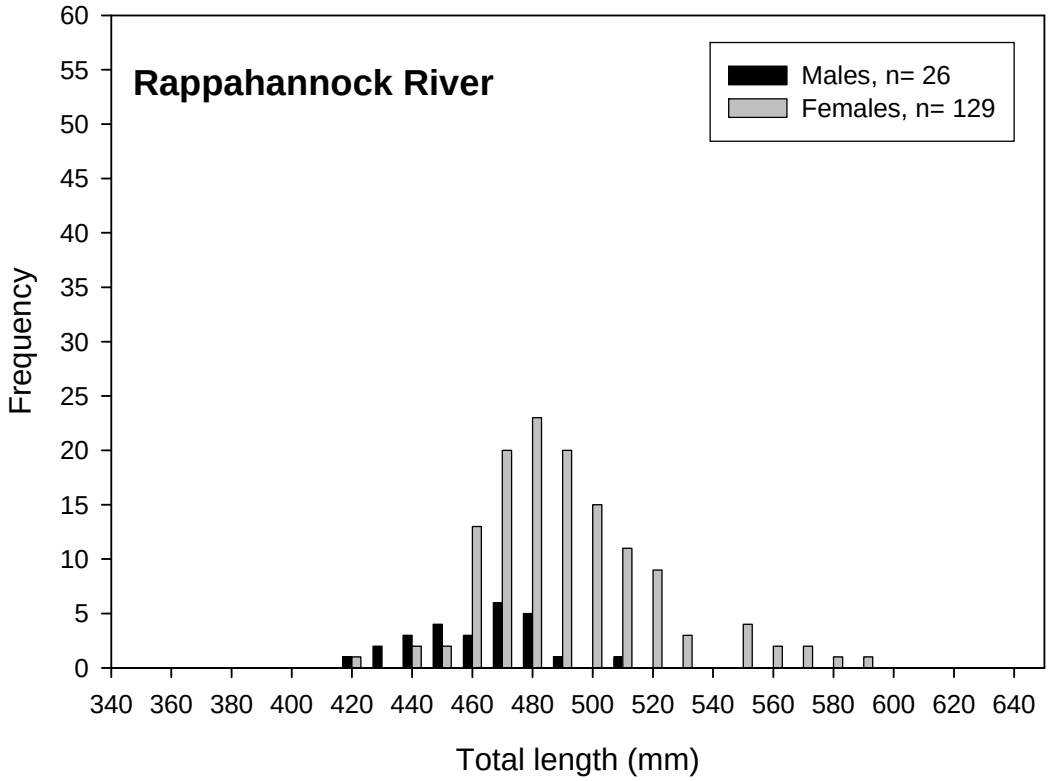
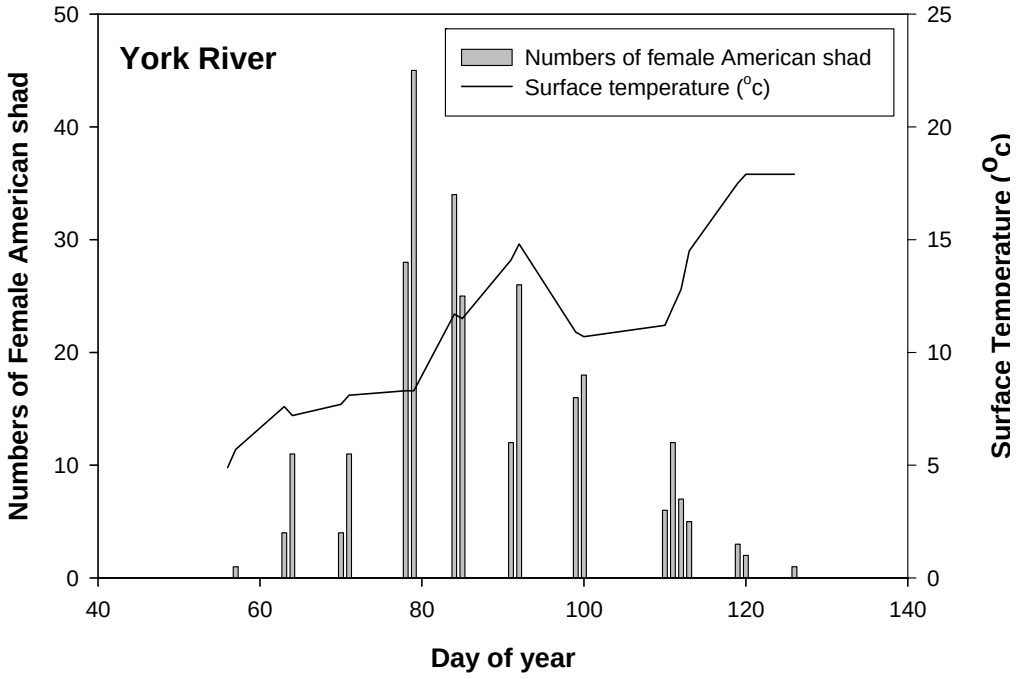


Figure 16. Total numbers of American shad caught and surface temperature recorded at staked gill nets in the James and York Rivers, spring 2007.



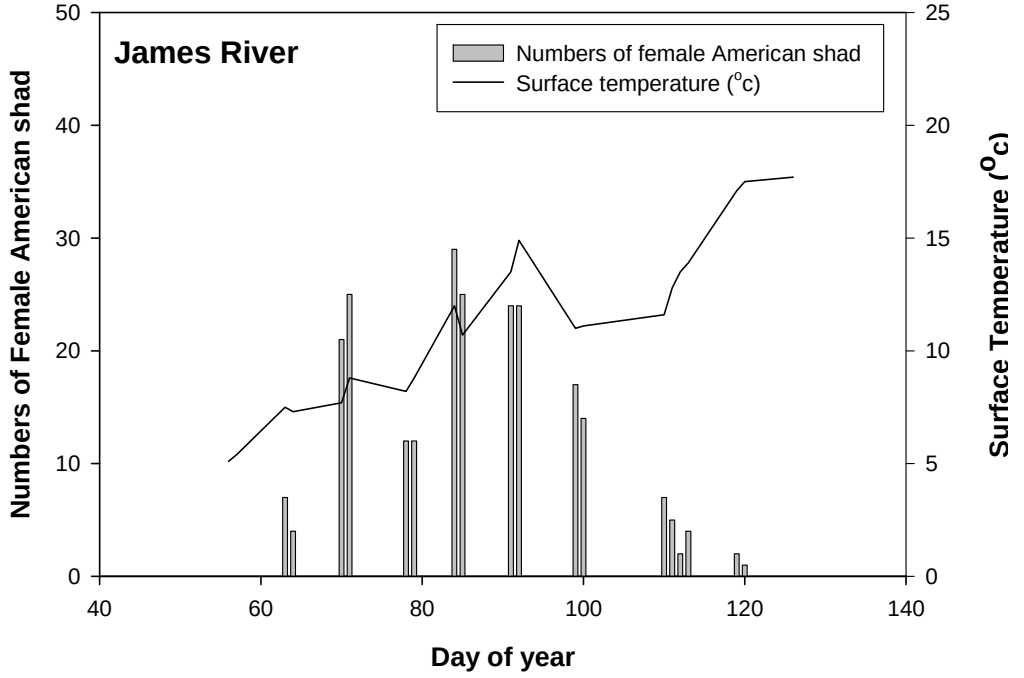


Figure 17. Total numbers of American shad caught and surface temperature recorded at staked gill nets in the Rappahannock River, spring 2007.

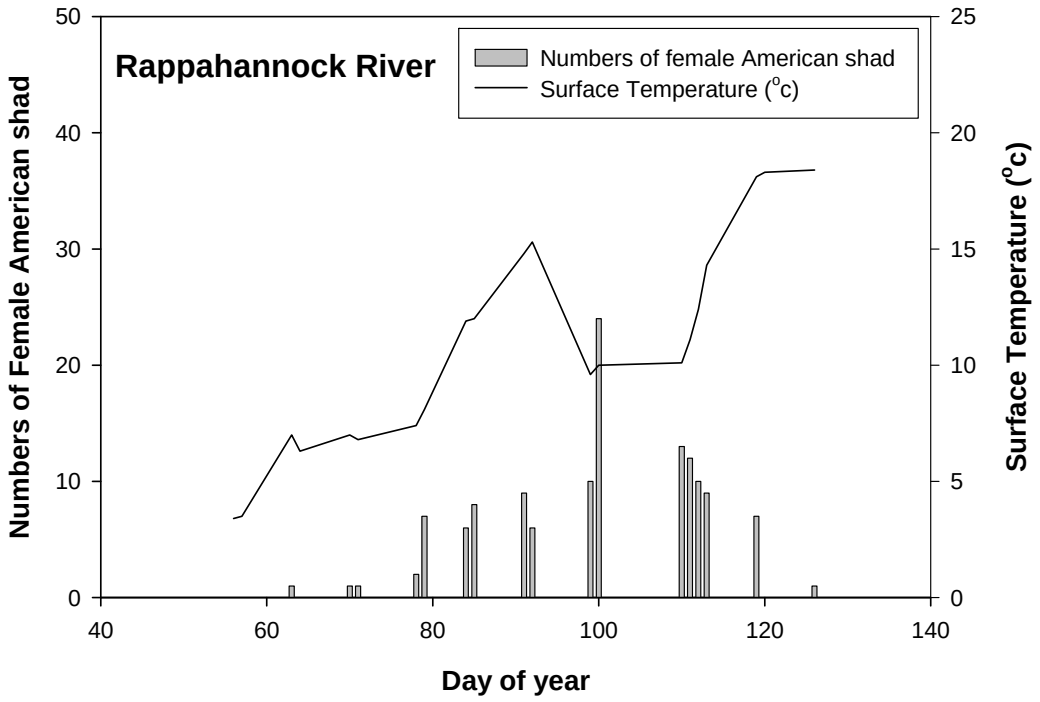


Figure 18. **The index of juvenile abundance of American shad in the York River system as estimated by daylight seine surveys, 1980-2007. The index is the geometric mean number of American shad juveniles per seine haul.**

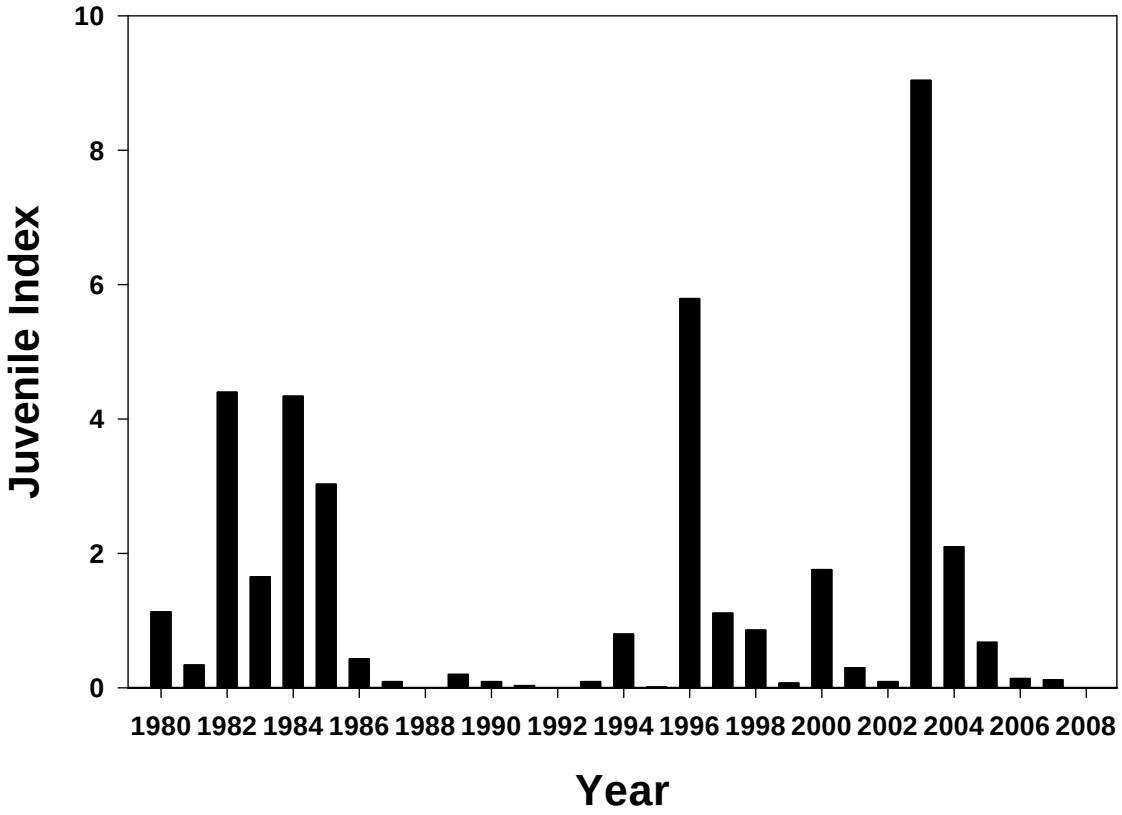


Figure 19. **The index of juvenile abundance of American shad in the Mattaponi and Pamunkey rivers as estimated by daylight seine surveys, 1980-2007. The index is the geometric mean number of American shad juveniles per seine haul.**

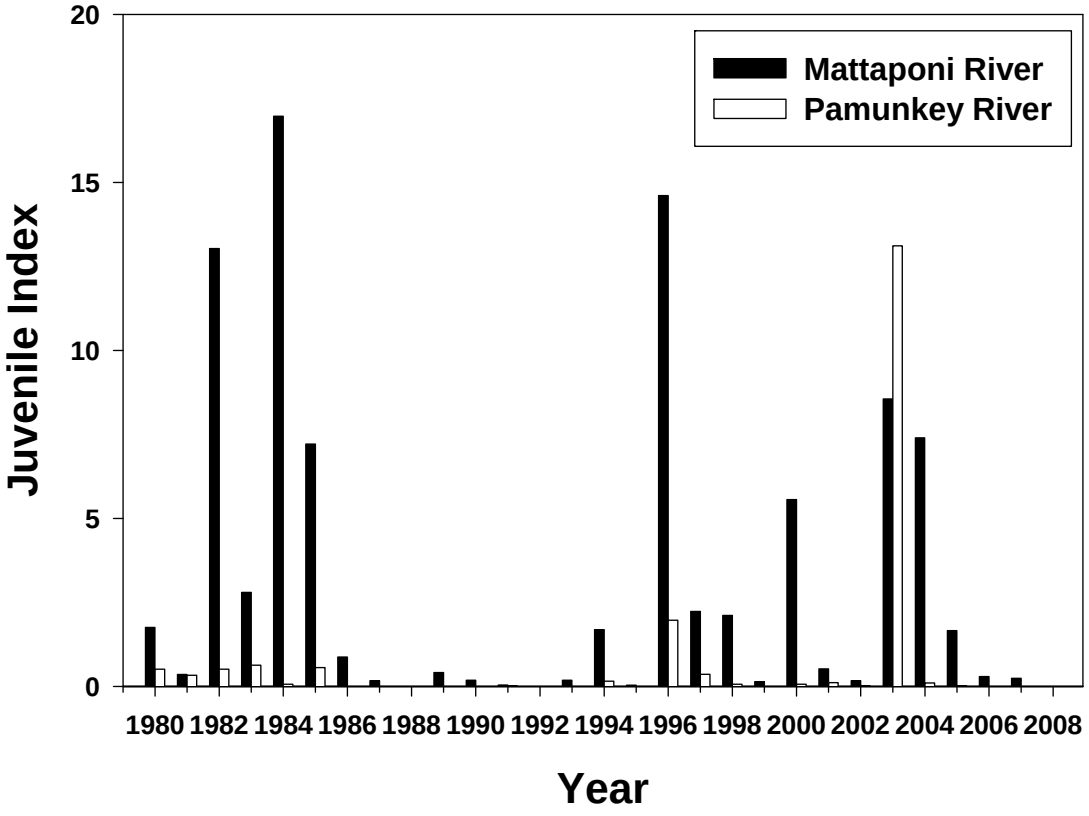


Figure 20. **The index of juvenile abundance of American shad in the Rappahannock River as estimated by daylight seine surveys, 1980-2007. The index is the geometric mean number of American shad juveniles per seine haul. The index in 1980 and 1981 was zero.**

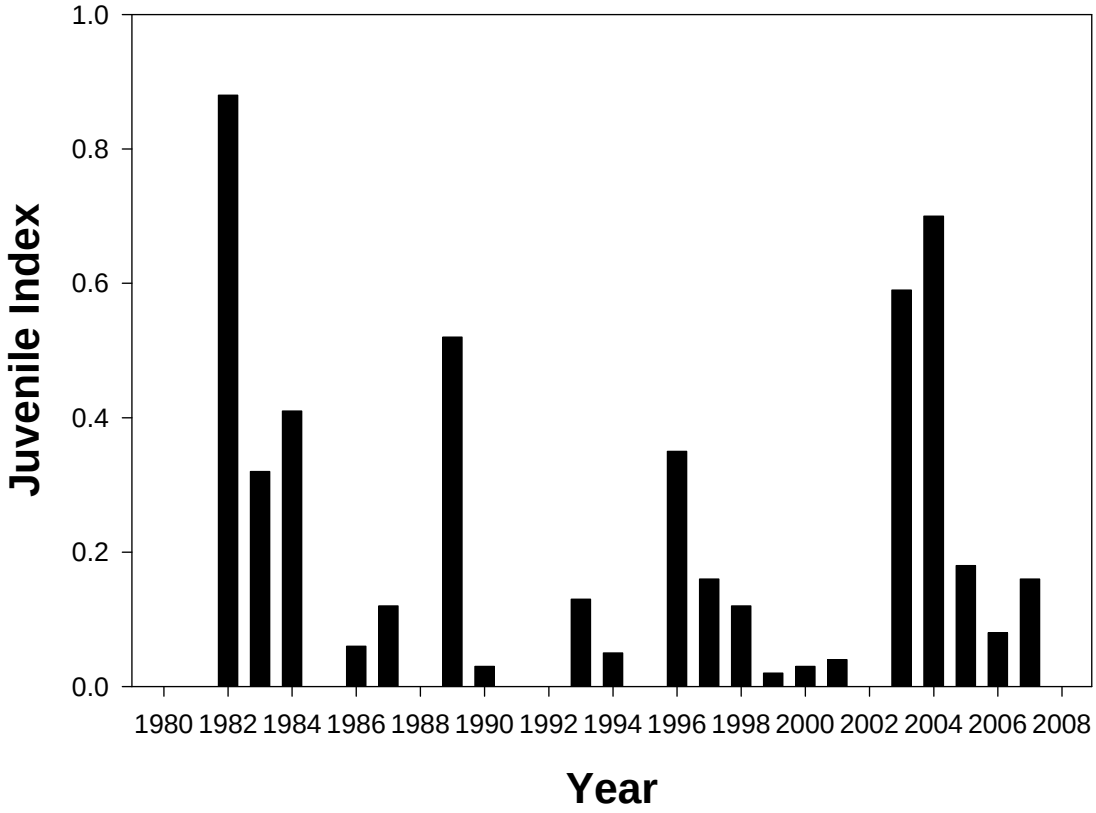


Figure 21. Mean age of females taken in staked gill nets in the James, York, and Rappahannock Rivers, 1998-2007.

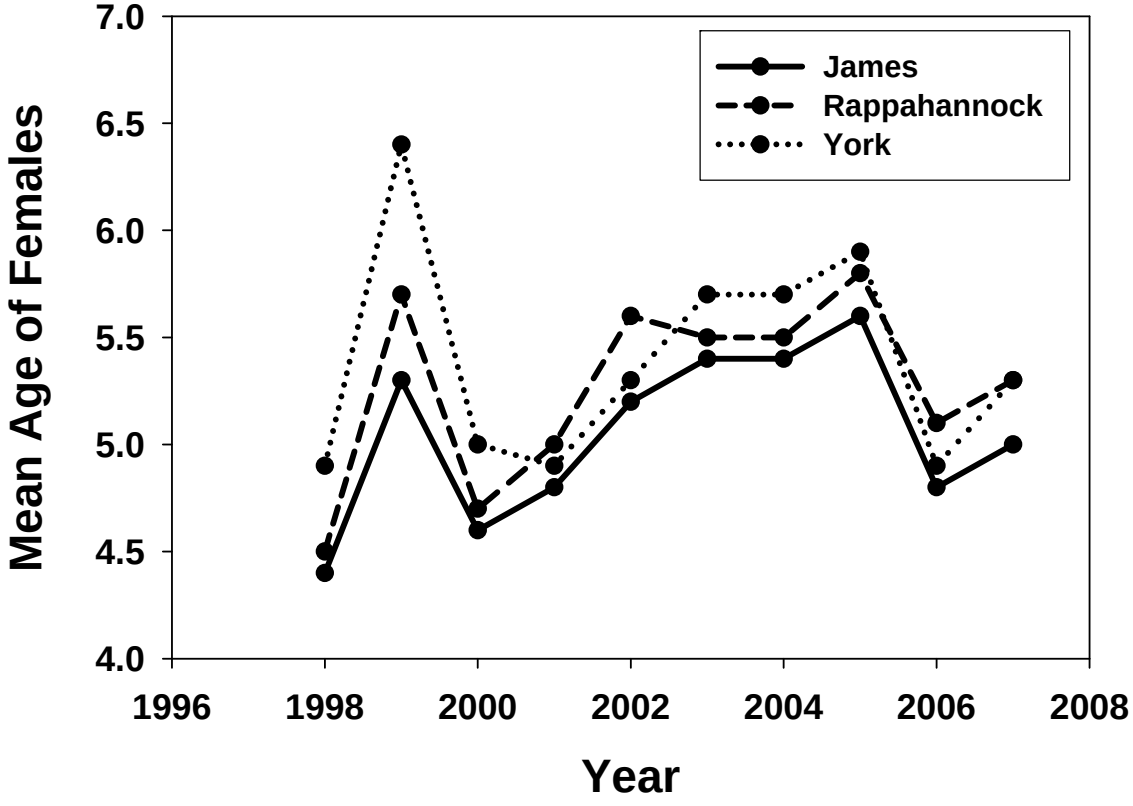


Figure 22. Mean age of females and the proportion of age-4 recruits in staked gill nets, 1998-2007.

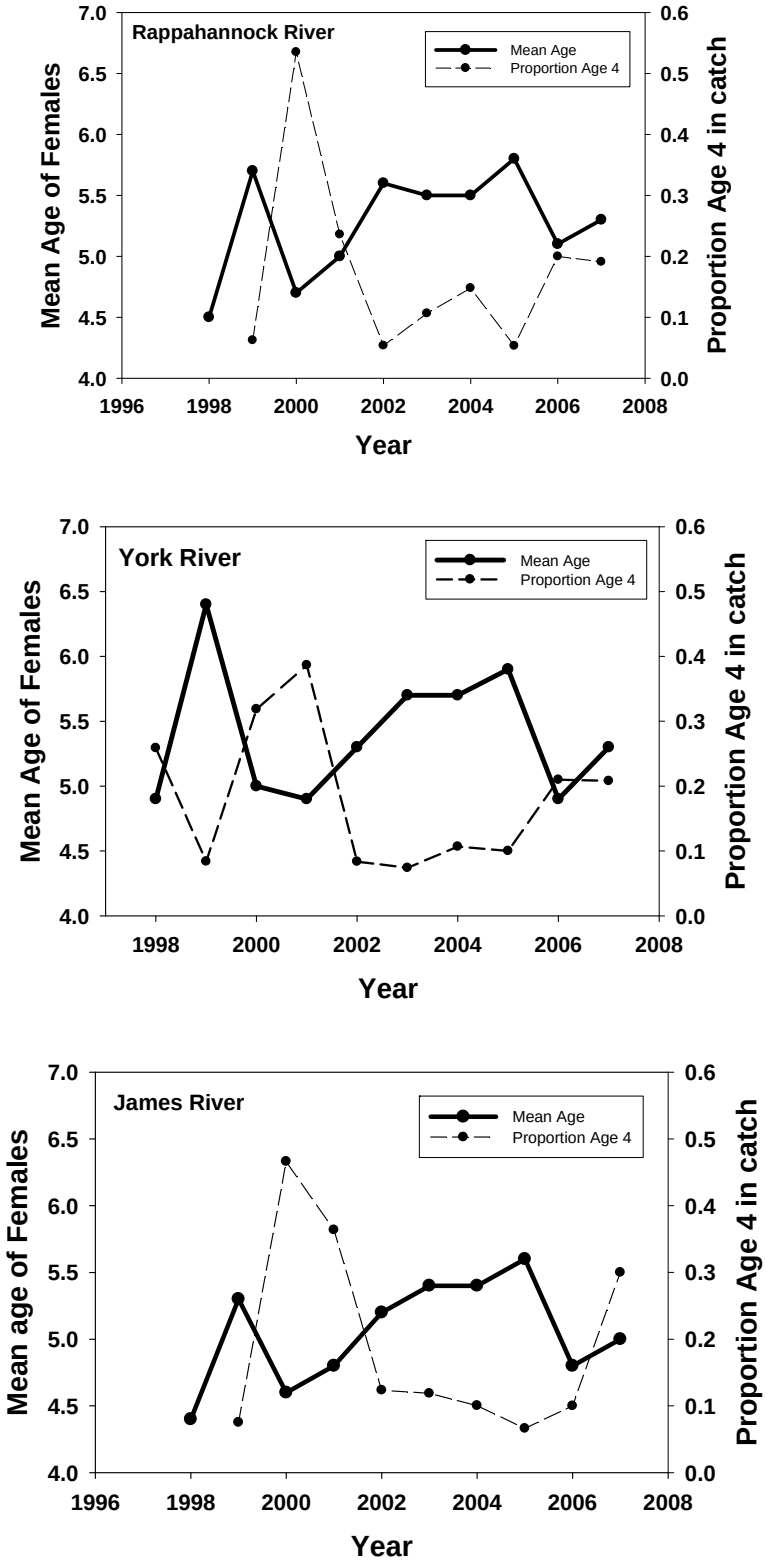


Figure 23. Recent (1998-2007) and historic values of the catch index of female American shad on the James River.

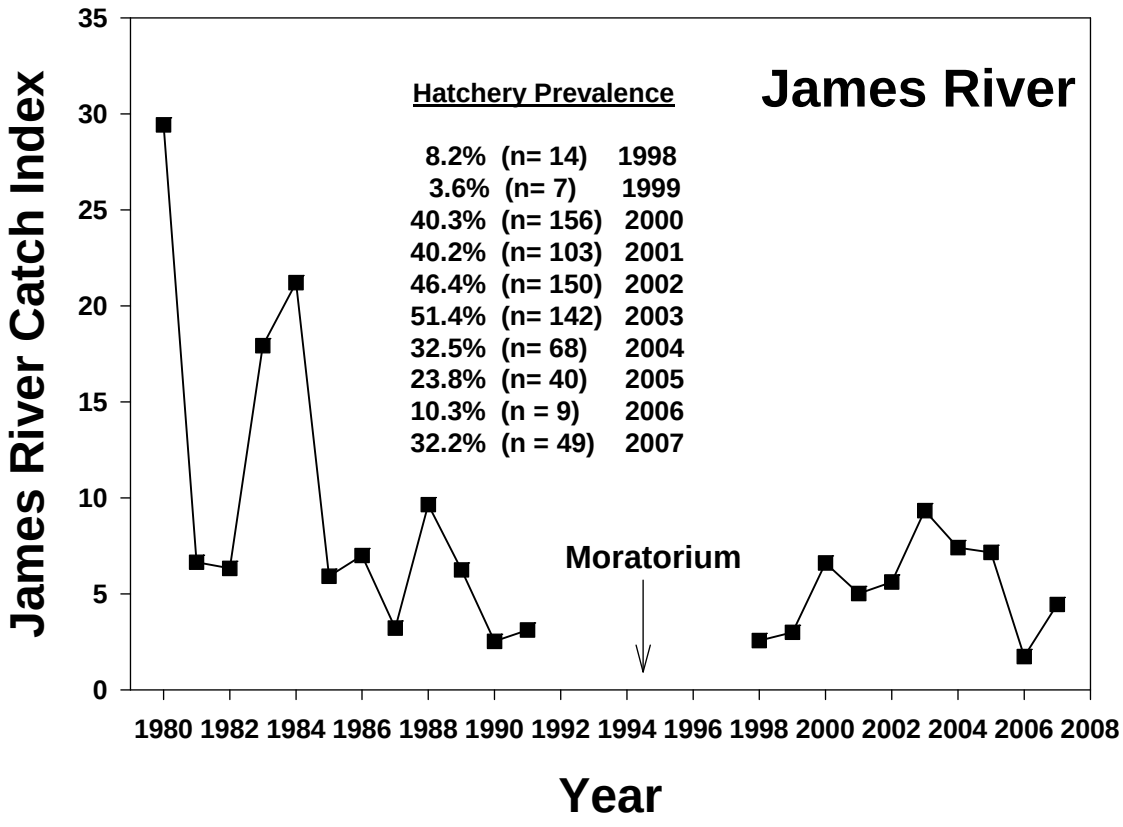


Figure 24. **Recent (1998-2007) and historic values of the catch index of female American shad on the York River.**

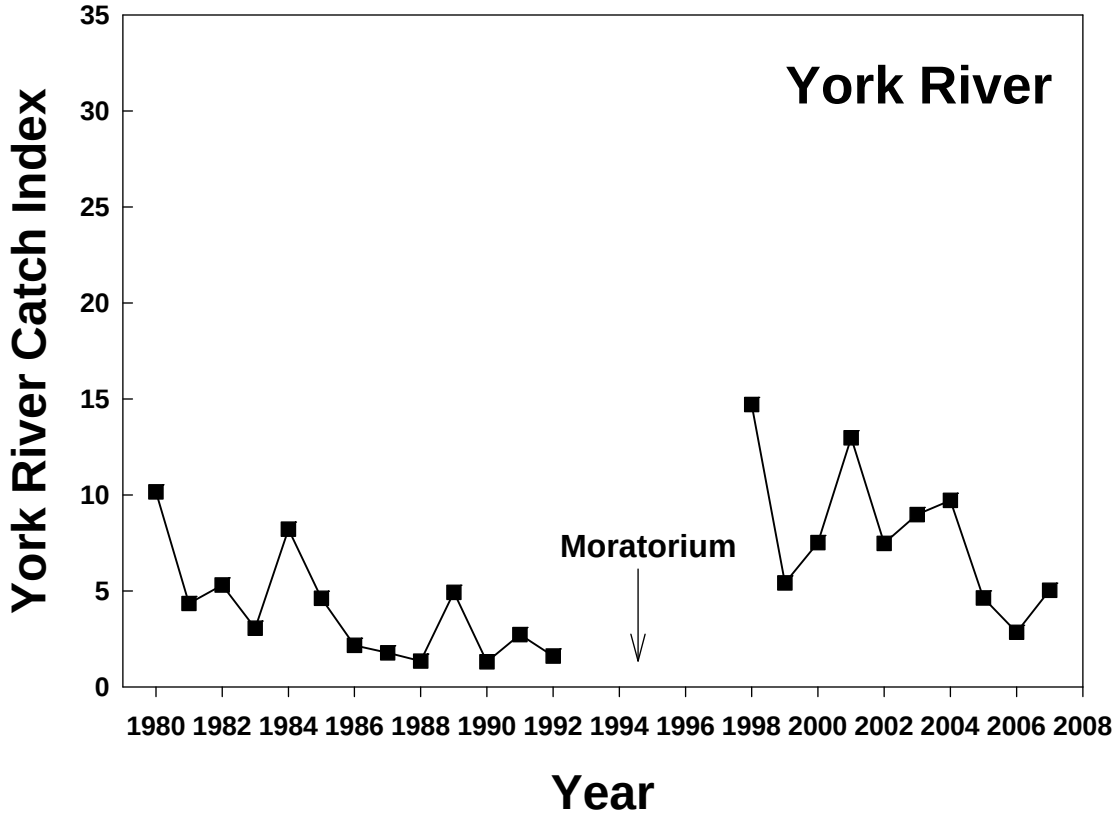


Figure 25. **Recent (1998-2007) and historic values of the catch index of female American shad on the Rappahannock River.**

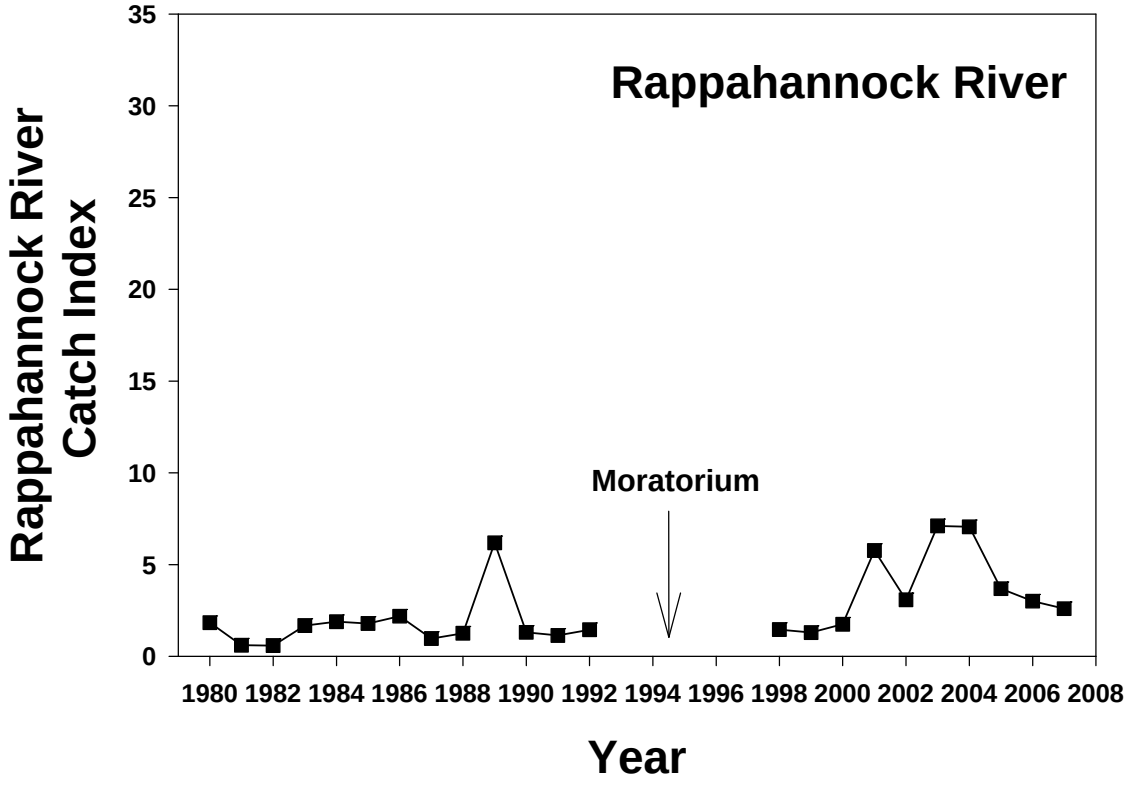
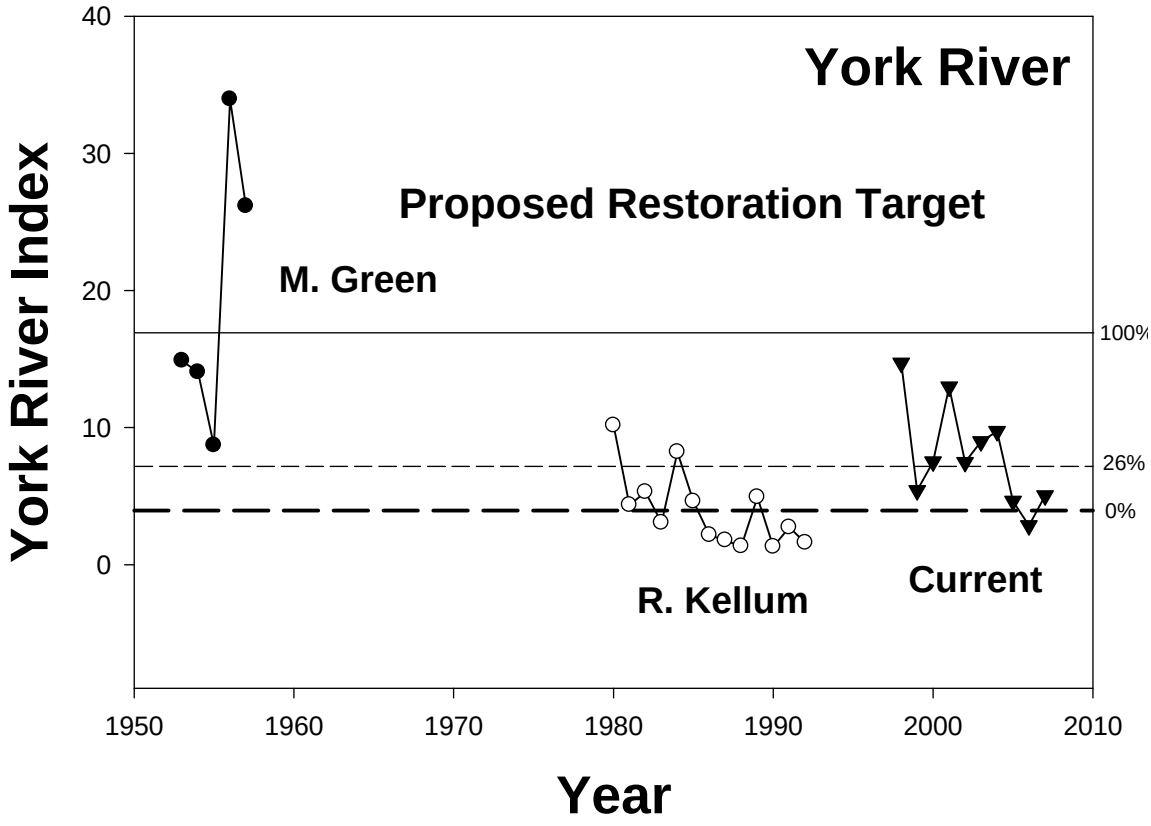


Figure 26. **Catch indexes of historical logbook data from the 1950s (M. Greene), 1980s (R. Kellum), and current monitoring. The 1950s data have been adjusted by multiplying index values by 2.16 based on gear comparison trials. Horizontal lines are the means of each data set (solid, 1950s; short dashes, current; long dashes, 1980s)**



Appendix I

Assessment of the 2007 Virginia by-catch of American shad and the status of the Virginia stocks – submitted to the Atlantic States Marine Fisheries Commission, December 2007

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Background

In spring 2007, scientists at the Virginia Institute of Marine Science (VIMS) interviewed permitted fishers who had agreed to participate in the ASMFC required monitoring program and obtained samples of their by-catch of American shad. This report summarizes the results of by-catch monitoring and the current status of the stocks in the James, York and Rappahannock rivers based on fishery-independent monitoring of the spawning stock, 1998-2007. An ASMFC assessment of these stocks (using available data from up to 2005) was approved by the Shad and River Herring Management Board in 2007. The assessment and supporting documents are available at the ASMFC web site.

This report is a companion to a separate report of the 2007 by-catch prepared by the Virginia Marine Resources Commission (VMRC) and submitted separately.

Biological Characterization of the 2007 Permitted Gill Net By-Catch in Virginia

A subsample of the 2007 by-catch of American shad (n= 52 fish, 19.2% of the total number of fish reported to VMRC) was obtained from cooperating gill netters and processed for length, weight, sex, maturity stage, age, and the presence of hatchery (OTC) marks.

Telephone surveys were conducted weekly with seven cooperating fishers who obtained by-catch permits on the James, York, and Rappahannock Rivers (Table 1). Estimates of catch rates (weight per length of net or numbers of fish per trip) were available for a portion of the sample (n=49). Some collections were obtained from multi-mesh nets that lacked data on length of net so these collections are excluded from the summary data.

Catch and effort information are recorded for each date of harvest in Tables 2-3. Based on telephone interviews, catch per trip varied from 1-6 fish and averaged 1.3 fish/trip among all cooperating fishers. Mean catch rate of individual fishers varied from 1-3.1 (Table 2). The overall catch rate calculated from data reported to VMRC was 1.5 fish per trip (271 fish/185 trips).

The by-catch subsample contained 3 males and 49 females. Most of the subsample was harvested in anchored gill nets (n= 51) with only 1 fish taken in staked gill nets. The subsample contained fish captured in the York River (n= 41), James River (n=9), and Rappahannock River (n=2). Most of the sub-sample was taken in 5.5-inch stretched mesh nets (Figure 1). The subsample ranged in size and age from 398-582 mm TL and 4-11 years (Figure 2). Sample sizes are small and comparisons with fishery-independent monitoring data are difficult. Size frequencies appeared not to differ markedly among the mesh sizes (Figure 3). The size frequency distribution of the by-catch subsample was within the size frequency distribution of the fishery-independent staked gill net monitoring sample (Figure 4). Size frequency distributions of the bycatch subsample were similar in all rivers (Figure 5).

Only one hatchery-produced American shad was present in the by-catch subsample. This fish was caught in the York River and was identified with a Pamunkey River specific marking sequence released from 2000-2001. The mark was identified as a fish released by the Pamunkey Indian tribal government. This fish was female, 532 mm TL and age 6.

By-Catch and Discards by Pound Nets in Virginia

In addition to the permitted by-catch samples of American shad taken in gill nets, VIMS scientists examined pound net samples and daily log books of catches from four pound net fishers operating at locations in the upper and lower portions of Chesapeake Bay including the western and eastern shores (Figure 6). These monitoring efforts were expanded from 2006 to include three additional fishers. Pound net fishers had special permits to take American shad for scientific monitoring.

Samples of up to 48 American shad were collected from each pound net fisher at intervals of approximately every two weeks (Figure 7). Fish in these samples were taken randomly from the total catch on a given day or represented the entire catch from a single net. Some samples were taken more frequently when individual operations were catching American shad. A total of 563 American shad were processed for length, weight, sex, maturity stage, age, and the presence of hatchery (OTC) marks. Biological information is recorded for each date of harvest in Tables 4-7. Laboratory scans for hatchery marks and age determination are still in process.

Numbers of males captured were lower than numbers of females (208 males; 355 females). Sex ratios (males:females) were: Great Wicomico, 1:1.1; Lynnhaven Inlet, 1:3.93; Rappahannock River, 1:3.67; Cape Charles, 1:1.40. American shad collected from nets located on the western shore had similar average weights for both males and females (Tables 4-6). The net located at Cape Charles had smaller average weights compared to nets located on the western shore. Differences in average weight between the western and eastern shore nets can be contributed to maturity stage, which was macroscopically determined for females in the laboratory. Spawning ratios (prespawning:postspawning) of females were: Great Wicomico, 1:0; Lynnhaven Inlet, 1:.07; Rappahannock River, 1:.05; Cape Charles, 1:57.5. Our monitoring indicated that

post-spawning fish exiting the Chesapeake Bay were taken by pound nets on the eastern shore near the Bay mouth.

A VIMS scientist observed the operation of three cooperating pound net fishers on one day for each operator. We could not arrange a day of observation with the fourth operator. General notes on the number of American shad caught and condition upon release were taken. Pound nets were not similar in design and fishing methods and weather conditions encountered during fishing operations varied by location (Table 8). The observer estimated mortality experienced by American shad during fishing operations by observing the condition of fish as they were discarded. Fish were observed to swim vigorously, swim weakly, float or sink. Mortality estimates ranged from 50%-100% of American shad discarded. The observer noted that smaller catches of all fish species and calm conditions allowed a more efficient fishing operation and tended to result in lower mortality rates of discarded shad.

A total of 3128 discarded American shad were recorded in commercial log book records of three pound net fishers. A six-year time series of log book records is available from one fisher operating multiple nets off the mouth of the Great Wicomico River (Figure 8). 2007 log books were obtained from two fishers (Figure 9). We were unable to obtain logbooks from the fourth operator although we did purchase fish for biological characterization from those nets.

Pound net catches in the Great Wicomico River in March and April 2007 (1095 fish) were smaller than in 2003, 2005-6 and greater than in 2002 and 2004. The highest catches were recorded in 2003 (4413 fish). Catches of shad in the Rappahannock River were 767 fish in two pound nets in March and April 2007. Over 1200 post-spawning (either spent or partially spent) fish were reported in five pound nets near the Chesapeake Bay mouth in late May.

On average, catches of American shad in an individual pound net in our 2007 monitoring sample (3128/10 nets = 312 fish) exceeded the total allowed bycatch recorded by VMRC in all gill nets (271 fish) during the season.

Results of the 2007 Fishery-Independent Monitoring Studies

The catch index values (the area of the curve of catch rate versus day of the year) of pre-spawning American shad in fishery-independent staked gill net monitoring is depicted in Figure 10.

On the Rappahannock River, the 2007 index was 2.60, a value that contributes to a declining trend from peak values in 2003-4.

In 2007 the catch index on the James (4.45) and York rivers (5.35) was higher than the 2006 index. On the James River, the 2007 value was approximately equal to index values recorded in 1998-1999 prior to the influx of large numbers of hatchery fish (OTC scanning of the 2007 sample is in progress).

On the York River, the monitoring data suggest a three-year cycle of peak catches (beginning with the highest catch in 1998 when monitoring began), with the peak index value in each cycle smaller in the successive cycle. The trend of the York River monitoring data is a downward slope of catch index values through the 10-y time series.

Current Status of Virginia stocks

The 2007 stock assessment and peer-review advisory report (ASMFC 2007) noted that the James River shad stock was declining, the York River stock was increasing, and the Rappahannock River stock was stable at low levels of abundance. The independent panel noted that catch-curve analysis to estimate total mortality was less desirable than other methods but accepted the approach for the 2007 assessment given limitations in available data. The panel revised benchmark levels of Z_{30} based on a biomass-per-recruit model derived from York River data. With these revisions, benchmark Z_{30} is exceeded in all Virginia stocks during most years. Among other recommendations, the advisory report concluded that future management actions should reduce total mortality to below benchmark levels.

It is important to note that the recently approved 2007 stock assessment does not include fishery-independent data in 2006 and 2007 (Figures 10-14). These new data indicate the catch index on the York River continues to decline sharply. The index values in 2005-2007 are within the 95% confidence range of the 1980s data when the fishery was collapsing on the York River (Figure 11). Although the mean of the 10-year time series of fishery-independent data is greater than the 1980s mean based on commercial logbooks, the York River catch index is decreasing. The current level of catch rates on the York River are well below benchmark restoration levels established using 1950s data. The current mean catch index on the York River stock is approximately 26% of the benchmark recovery level (Figure 12).

Monitoring data in 2006-2007 on the James and Rappahannock rivers suggests no improvement or substantial change of status since the 2007 assessment. As indicated above, a declining trend in catch index values is noted on the Rappahannock River since 2005.

Table 1. Summary of telephone surveys conducted by VIMS for American shad bycatch in the Rappahannock, York, and James rivers from 1/28/2007 - 4/18/2007. Numbers are weekly totals of American shad caught by fisherman. Number in parenthesis indicates specimens that were brought back to VIMS laboratory for inspection. Abbreviations are: Rapp, Rappahannock River; AN, anchored gill net; SGN, staked gill net; asterisk (*), not fishing. Blank cells are weeks of no interviews.

River	Fisher	Gear	Week											
			1/28	2/4	2/11	2/18	2/25	3/4	3/11	3/18	3/25	4/4	4/11	4/18
Rapp	1	AN			0	1(1)		0						
Rapp	2	AN					1	1(1)						
York	3	SGN	*	*	0	1(1)	*	*	*	*	*	*	*	*
York	3	AN	*	*	*	*	0	0	0	*	*	*	*	*
York	4	AN	*	*	*	*	*	*	*	3(3)	29(28)	9(9)	1	1
James	5	AN			1(1)	0	1(1)		3(3)	1(1)		2(1)		2(2)
James	6	AN			0	0	*	*	*	0	0	0	*	*
James	7	SGN	*	*	*	*	*	*	*	0	0	0		

Table 2. Catch per unit effort (CPUE, kg/m/d and numbers/trip) associated with the subsample (n=49) of by-catch fish processed by VIMS.

River	Fisher	Total trips reporting shad	Total number of shad	Total Weight (kg)	Range of CPUE (kg/m/d)	Mean CPUE (kg/m/d)	Mean CPUE (N/trip)
RA	1	1	1	2.69	0.015	0.015	1.0
RA	2	1	1	2.73	0.005	0.005	1.0
YK	3	1	1	1.53	0.017	0.017	1.0
YK	4	13	40	75.19	0.0075-0.047	0.0237	3.1
JA	5	5	6	9.33	0.0064-0.023	0.015	1.2

Table 3. Catch per unit effort (CPUE) by sampling date for American shad by-catch samples processed at VIMS. Abbreviations are : JA; James River, YK; York River, RA; Rappahannock River, *; Did not obtain whole sample

River	DateFished	Fisherman	Gear	Net	Mesh (in)	Net Length (ft)	Number of shad	Sex	Effort (days)	CPUE (N/m/d)	Weight_sum	CPUE_Wt
JA	2/12/2007	5	AGN	1	6	600	1	F	2	0.003	2339.4	0.064
YK	2/22/2007	3	SGN	1	6	300	1	F	1	0.011	1525.5	0.167
RA	2/24/2007	1	AGN	1	6.50	600	1	F	1	0.006	2691.1	0.147
JA	2/28/2007	1	AGN	1	6	600	1	M	1	0.006	1845.8	0.101
RA	3/5/2007	2	AGN	3	3.125	300	1	F	2	0.006	2727.3	0.149
JA	3/13/2007	5	AGN	3	5	300	2	M	1	0.022	2093.2	0.229
JA	3/14/2007	5	AGN	3	5	300	1	F	1	0.011	1809.8	0.198
JA	3/20/2007	5	AGN	3	5	300	1	F	1	0.011	1240.9	0.136
YK	3/23/2007	4	AGN	1	5.50	800	2	F	1	0.008	3622.4	0.148
YK	3/24/2007	4	AGN	1	5.50	800	1	F	1	0.004	2098.0	0.086
YK	3/25/2007	4	AGN	1	5.50	800	6	F	1	0.025	*	*
YK	3/26/2007	4	AGN	1	5.50	800	4	F	1	0.016	7551.3	0.309
YK	3/27/2007	4	AGN	1	5.50	800	1	F	1	0.004	1917.4	0.079
YK	3/27/2007	4	AGN	1	5.50	800	1	M	1	0.004	712.7	0.029
YK	3/28/2007	4	AGN	1	5.50	800	6	F	1	0.025	11345.3	0.465
YK	3/30/2007	4	AGN	1	5.50	800	1	F	1	0.004	2081.6	0.085
YK	3/31/2007	4	AGN	1	5.50	800	4	F	1	0.016	7846.8	0.322
YK	4/1/2007	4	AGN	1	5.50	800	3	F	1	0.012	5370.3	0.220
YK	4/2/2007	4	AGN	1	5.50	800	3	F	1	0.012	5678.6	0.233
YK	4/3/2007	4	AGN	1	5.50	800	1	F	1	0.004	1827.2	0.075
YK	4/4/2007	4	AGN	1	5.50	800	5	F	1	0.020	9251.2	0.380
YK	4/10/2007	4	AGN	1	5.50	800	3	F	1	0.012	6340.3	0.260

Table 4. Biological data of American shad (n=185) collected from a pound net located at the mouth of the Great Wicomico River. Abbreviations are: TW; total weight, Avg; Average, P. Spent; Partially Spent

Date	Maturity Stage	# Females	TW (kg)	Avg Weight Per fish (g)	# Males	TW (kg)	Avg Weight Per fish (g)
3/26/2007	Maturing	23	32.5	1414.3			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				30	26.4	881.0
4/5/2007	Maturing	41	56.5	1378.7			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				37	30.1	813.5
4/24/2007	Maturing	33	45.8	1387.4			
	Hydrated						
	P. Spent						
	Spent						
	Unstaged				21	17.6	837.1
Total		97	134.8	1389.7	88	74.1	842.0

Table 5. Biological data of American shad (n=69) collected from a pound net located at the mouth of Lynnhaven Inlet. Abbreviations are: TW; total weight, Avg; Average, P. Spent; Partially Spent

Date	Maturity Stage	# Females	TW (kg)	Avg Weight Per fish (g)	# Males	TW (kg)	Avg Weight Per fish (g)
5/2/2007	Maturing	6	7.1	1183.7			
	Hydrated	1	1.0	1023.2			
	P. Spent	1	0.9	890.4			
	Spent						
	Unstaged						
5/4/2007	Maturing	41	60.5	1476.3			
	Hydrated	3	4.6	1526.8			
	P. Spent	2	1.7	853.7			
	Spent	1	1.0	1038.4			
	Unstaged				14	13.0	926.1
Total		55	76.9	1398.2	14	13.0	926.1

Table 6. Biological data of American shad (n=112) collected from a pound net located at the mouth of the Rappahannock River. Abbreviations are: TW; total weight, Avg; Average, P. Spent; Partially Spent

Date	Maturity Stage	# Females	TW (kg)	Avg Weight Per fish (g)	# Males	TW (kg)	Avg Weight Per fish (g)
4/17/2007	Maturing	26	36.0	1382.2			
	Hydrated	1	1.8	1795.0			
	P. Spent						
	Spent						
	Unstaged				3	2.8	922.9
4/27/2007	Maturing	37	51.7	1396.9			
	Hydrated						
	P. Spent	1	0.8	802.5			
	Spent	1	0.7	714.7			
	Unstaged				7	5.7	819.9
5/8/2007	Maturing	6	7.7	1281.6			
	Hydrated						
	P. Spent						
	Spent	1	1.1	1119.3			
	Unstaged				7	7.1	1020.3
5/12/2007	Maturing	13	17.2	1321.6			
	Hydrated	1	1.0	1025.2			
	P. Spent	1	0.9	887.7			
	Spent						
	Unstaged				7	5.3	761.7
Total		88	118.9	1351.1	24	20.9	870.8

Table 7. Biological data of American shad (n=197) collected from a pound net located in the vicinity of Cape Charles, VA. Abbreviations are: TW; total weight, Avg; Average, P. Spent; Partially Spent

Date	Maturity Stage	# Females	TW (kg)	Avg Weight Per fish (g)	# Males	TW (kg)	Avg Weight Per fish (g)
5/17/2007	Maturing						
	Hydrated						
	P. Spent	40	35.3	881.7			
	Spent	8	7.7	958.1			
	Unstaged				16	11.9	742.4
5/21/2007	Maturing						
	Hydrated	1	1.4	1432.2			
	P. Spent	18	16.6	920.3			
	Spent	11	10.7	970.4			
	Unstaged				31	20.3	654.2
5/29/2007	Maturing	1	1.1	1111.6			
	Hydrated						
	P. Spent	15	13.2	879.8			
	Spent	21	19.4	923.6			
	Unstaged				35	25.3	722.3
Total		115	105.4	916.5	82	57.5	701.2

Table 8. Data and notes taken by a scientific observer of pound net fishing.

Fisher	Date	Location	Net number	Number of Heads	Bail Type	Culling Time (minutes)	Total Estimated Catch of all species (lbs)	Estimated Number of Shad	Estimated Mortality (%)
1	4/6/2007	G.Wicomico	1	2	Mechanical	15	3000	15	50
1	4/6/2007	G.Wicomico	2	2	Mechanical	15	3000	25	50
2	4/18/2007	Rappahannock	1	2	Mechanical	10	1000	3	50
2	4/18/2007	Rappahannock	2	2	Mechanical	10	1000	4	50
3	5/22/2007	Cape Charles	1	1	Hand	N/A	20	0	N/A
3	5/22/2007	Cape Charles	2	1	Hand	N/A	20	0	N/A
3	5/22/2007	Cape Charles	3	1	Hand	N/A	20	0	N/A
3	5/22/2007	Cape Charles	4	1	Hand	N/A	20	0	N/A
3	5/22/2007	Cape Charles	5	1	Hand	N/A	20	0	N/A
3	5/22/2007	Cape Charles	6	1	Hand	30	500	30	100%

Figure 1. The number of American shad captured by mesh size in the by-catch subsample (n= 49 fish).

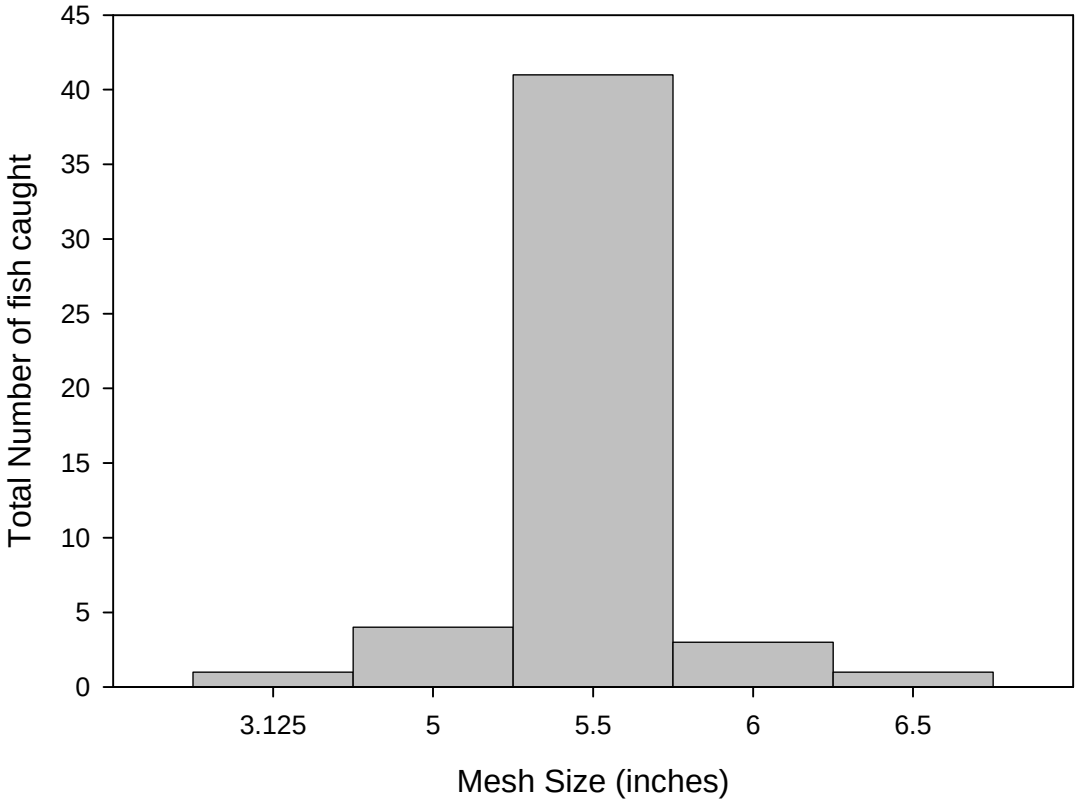
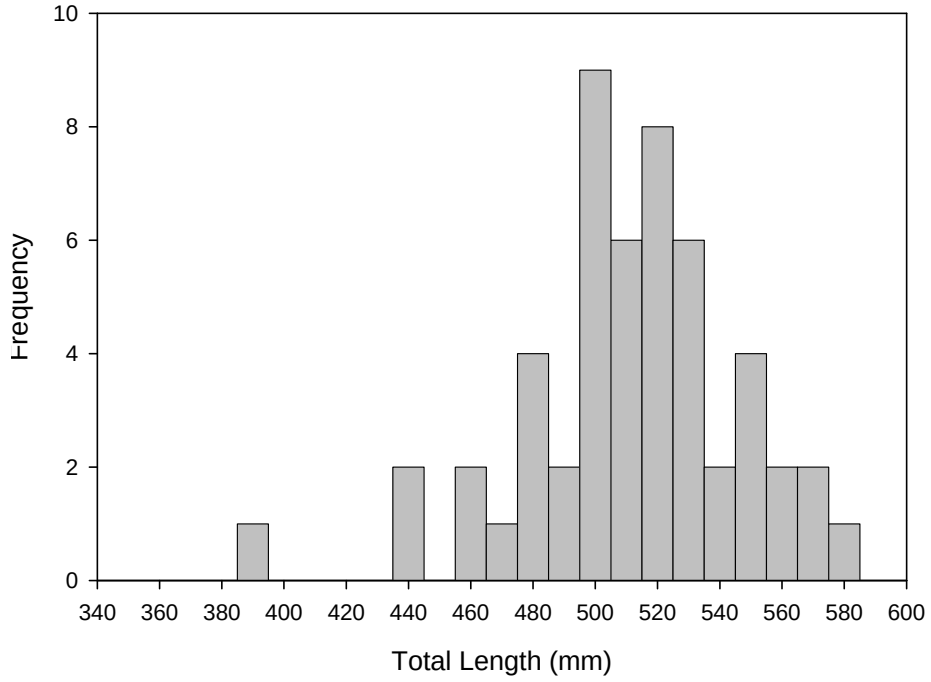


Figure 2. Size (upper panel) and age frequency (lower panel) of the by-catch subsample, 2007 (both sexes). Ages were determined by one reader using the methods of Cating 1953.



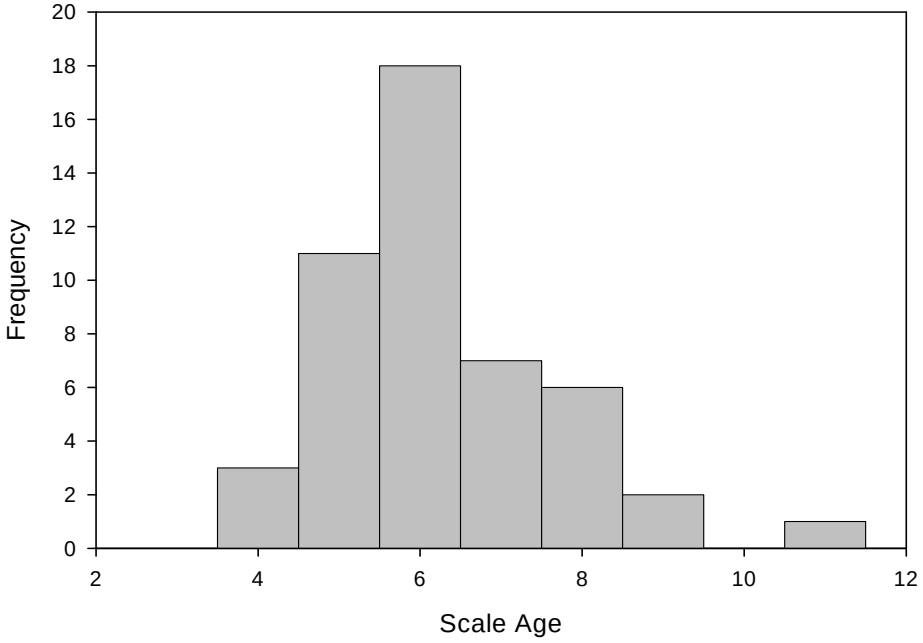


Figure 3. Size frequency of by-catch subsample by mesh size (both sexes).

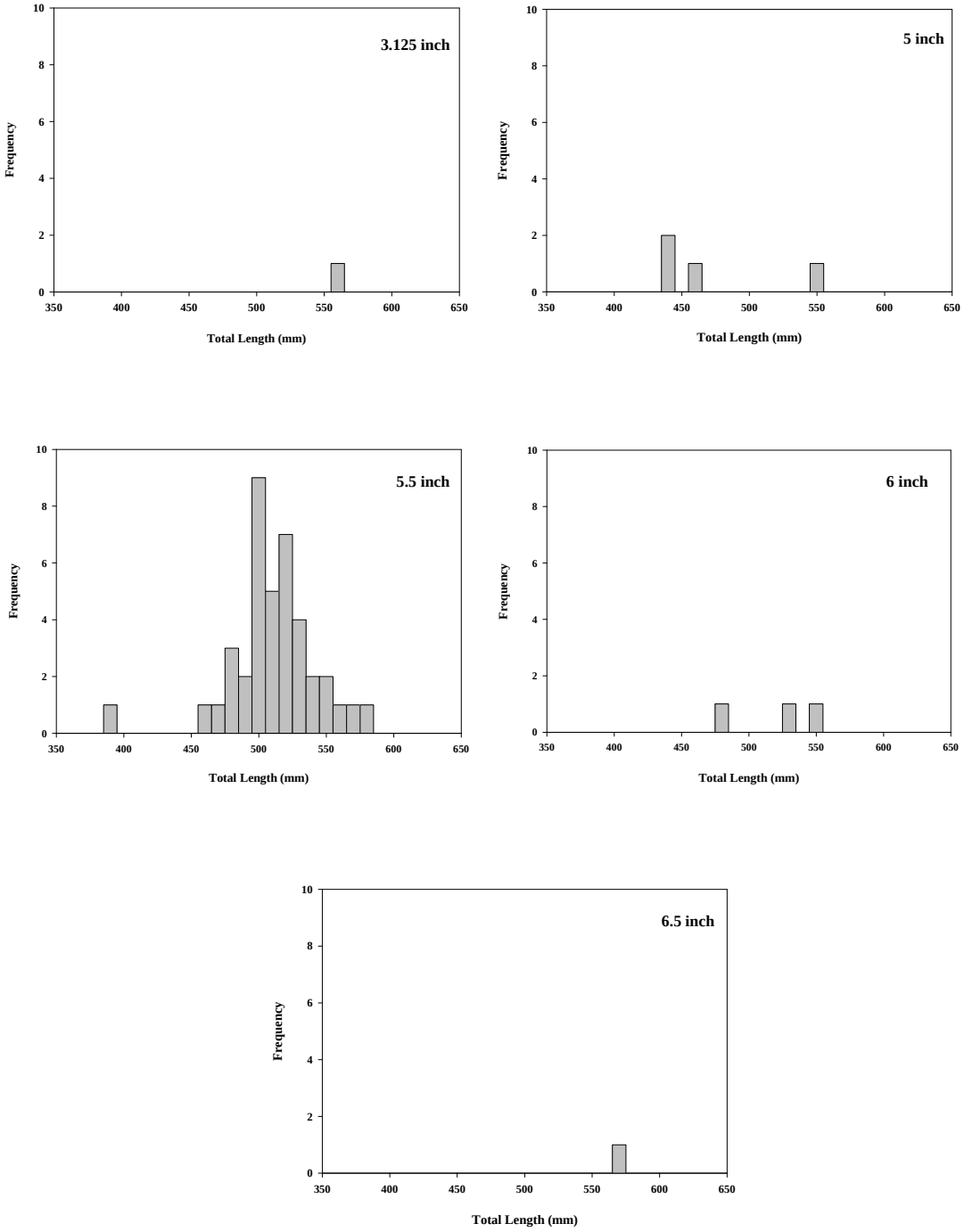


Figure 4. Comparison of size frequencies of the 2007 anchored gill net by-catch (3.125 to 7-inch streched mesh) and the 2007, staked gill net monitoring catch (4.88-inch stretched mesh) in the York.

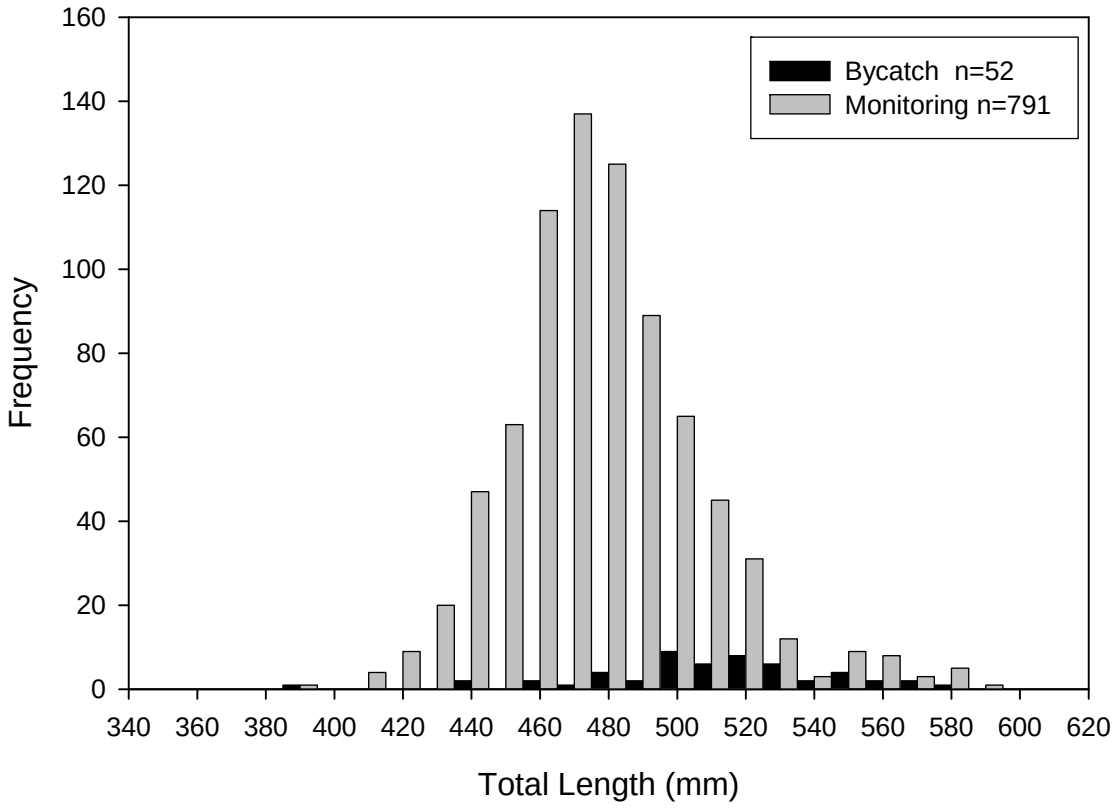


Figure 5. Comparison of size frequency distribution of the by-catch subsample by river.

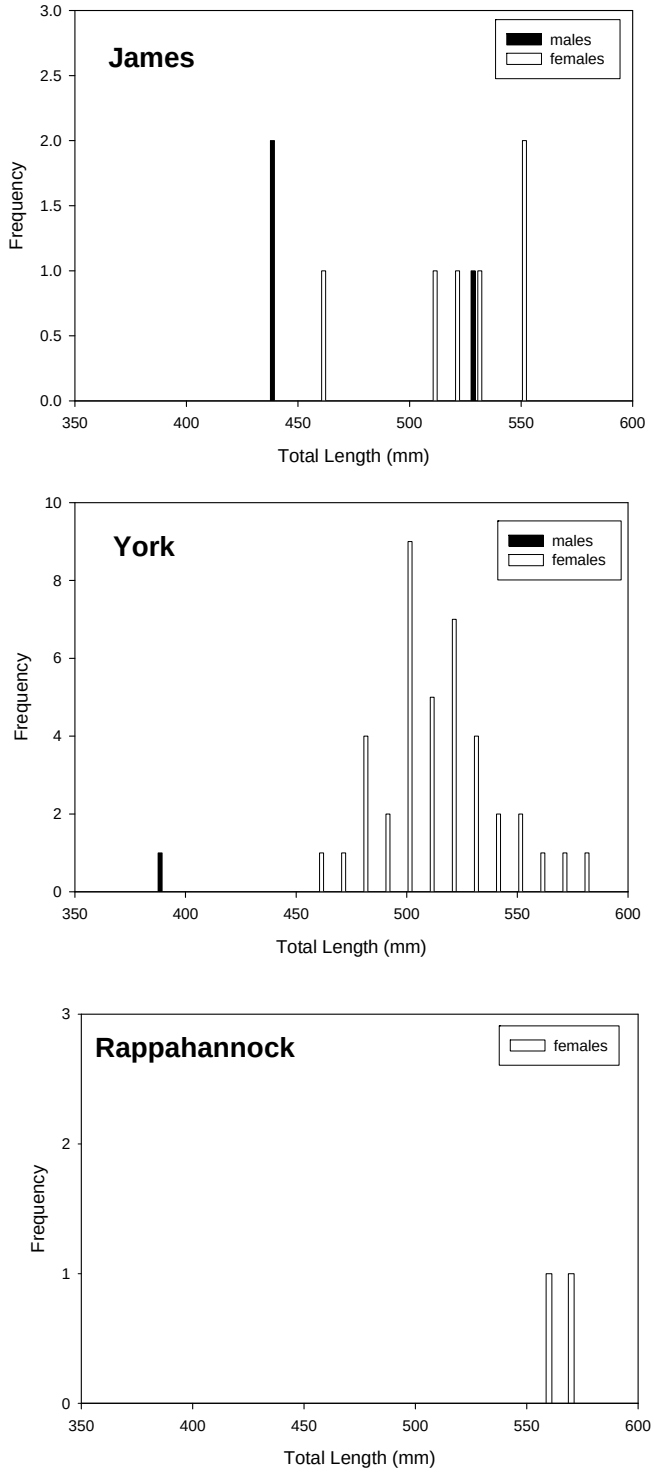


Figure 6. Location of pound net operations with special American Shad by-catch permits.

Figure 7. Number of American Shad processed by VIMS caught with special pound net by-catch permits. N is the number of fishing days sampled.

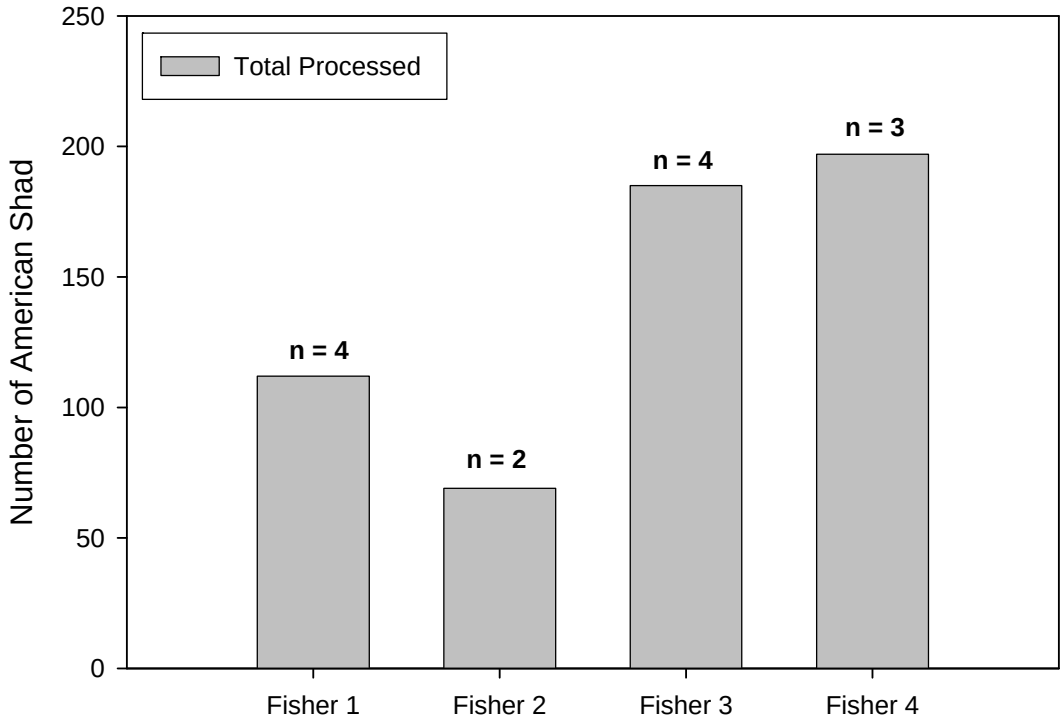


Figure 8. Catches (number of shad per trip) in pound nets located in the upper Virginia Chesapeake Bay near the Great Wicomico River. Data are taken from logbooks of a single commercial fisher in 2002-2007.

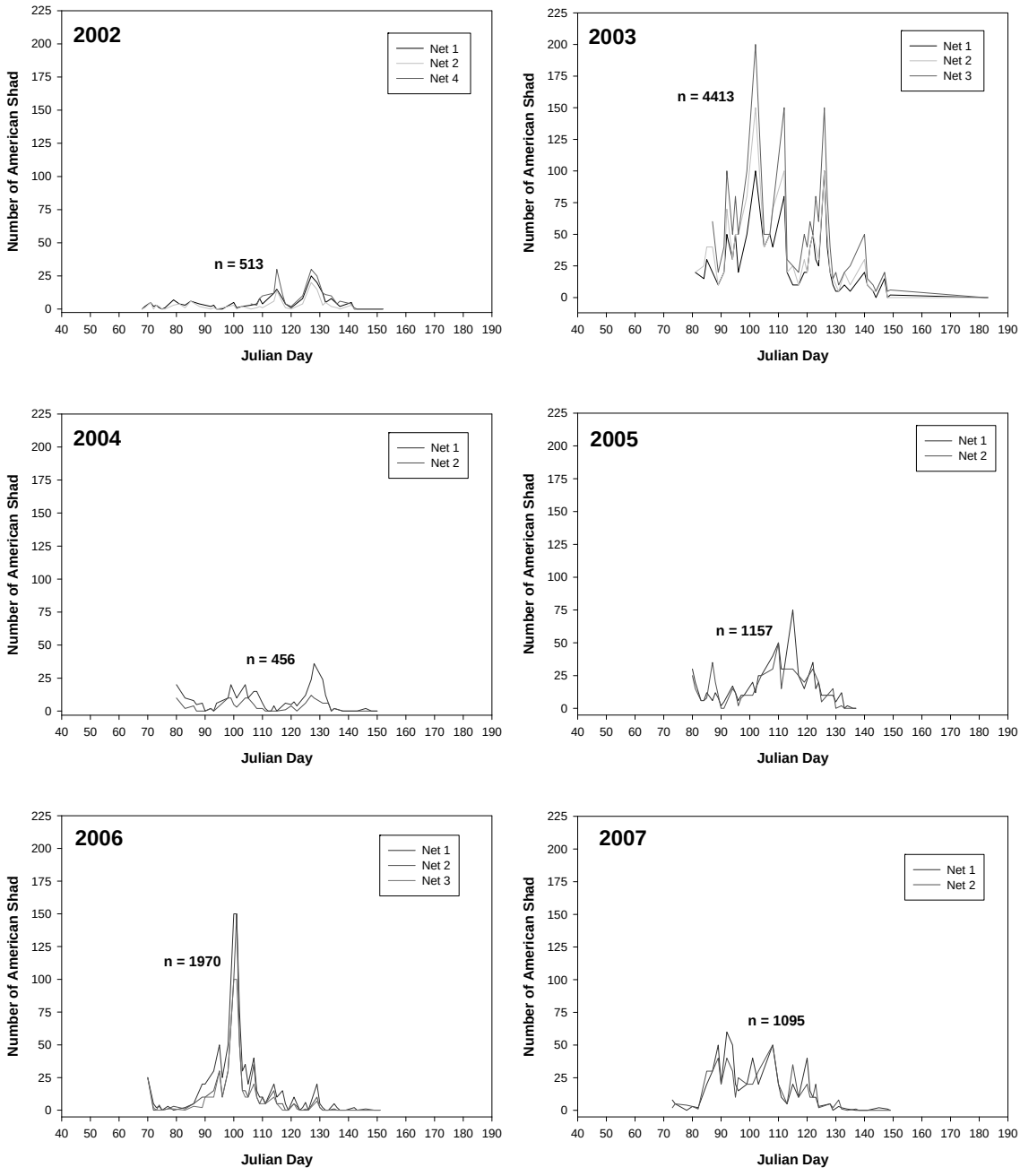
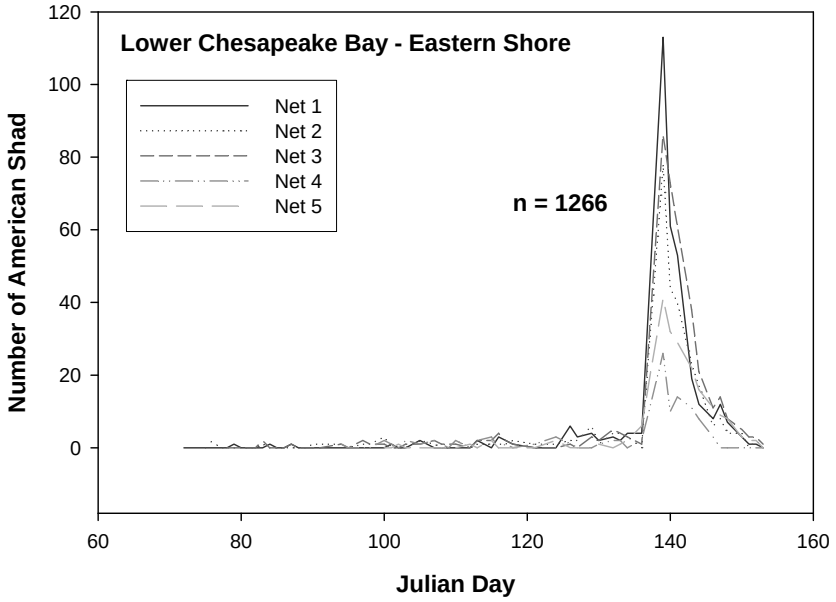


Figure 9. Catches (number of shad per trip) in pound nets located in the lower Virginia Chesapeake Bay near Cape Charles and the Rappahannock River mouth. Data are taken from 2007 commercial fisher logbooks.



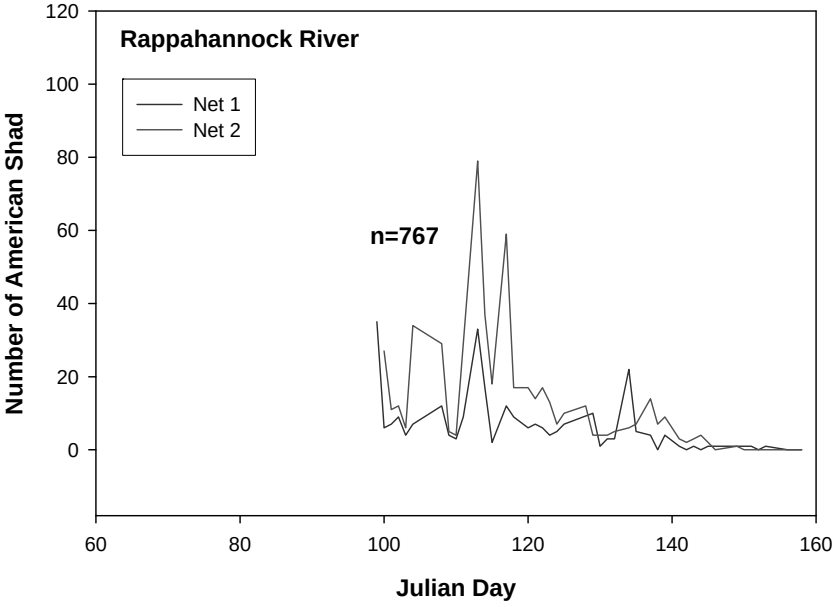


Figure 10. Time series of catch index from staked gill net monitoring in Virginia, 1998-2007.

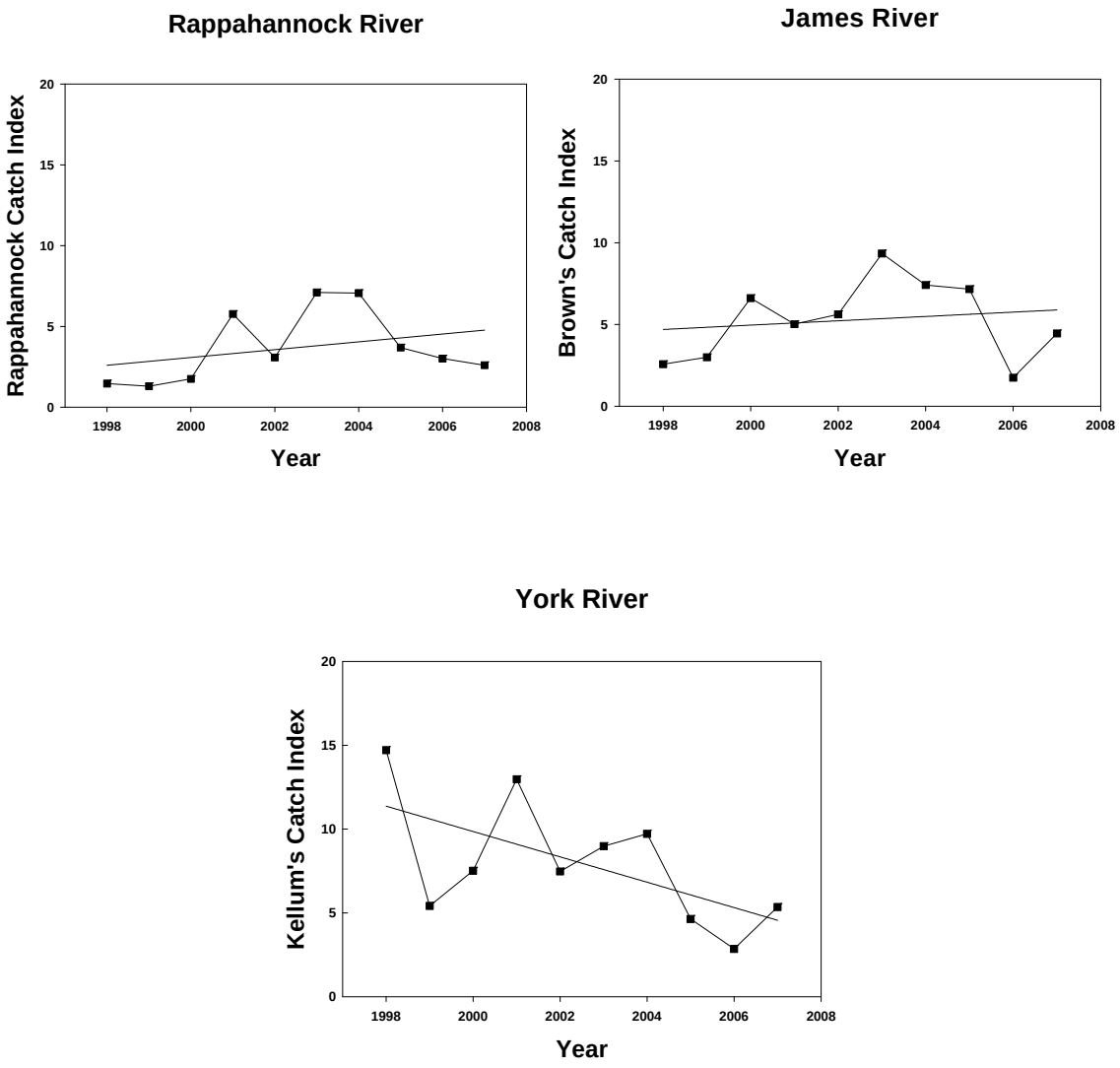


Figure 11. Comparison of recent (1998-2007) and historic (1980-1992) catch index values of American shad in the York River. Values of the catch index are calculated as the area under curve of daily catch versus time from commercial log books and from recent monitoring. Current monitoring is conducted on two successive days in each week from late February to the end of the run each year.

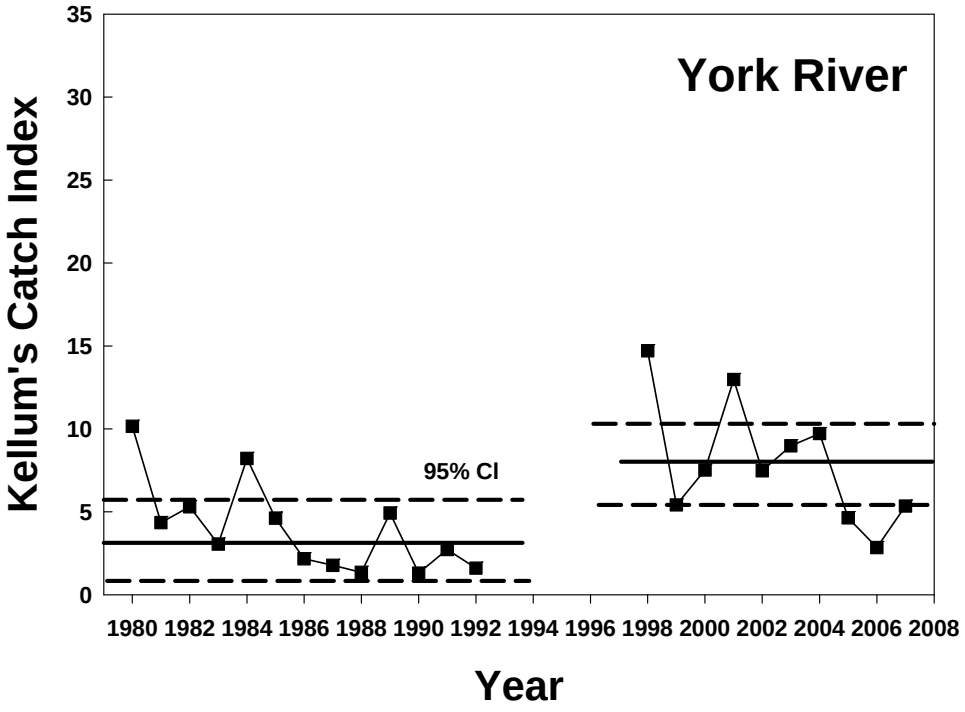


Figure 12. Comparison of recent (1998-2007) and historic (1953-1957, 1980-1992) catch index values of American shad in the York River. Values of the catch index are calculated as the area under curve of daily catch versus time from commercial log books and from recent monitoring. 1950s data are adjusted to account for gear differences (Maki et al. 2006). Current monitoring is conducted on two successive days in each week from late February to the end of the run each year.

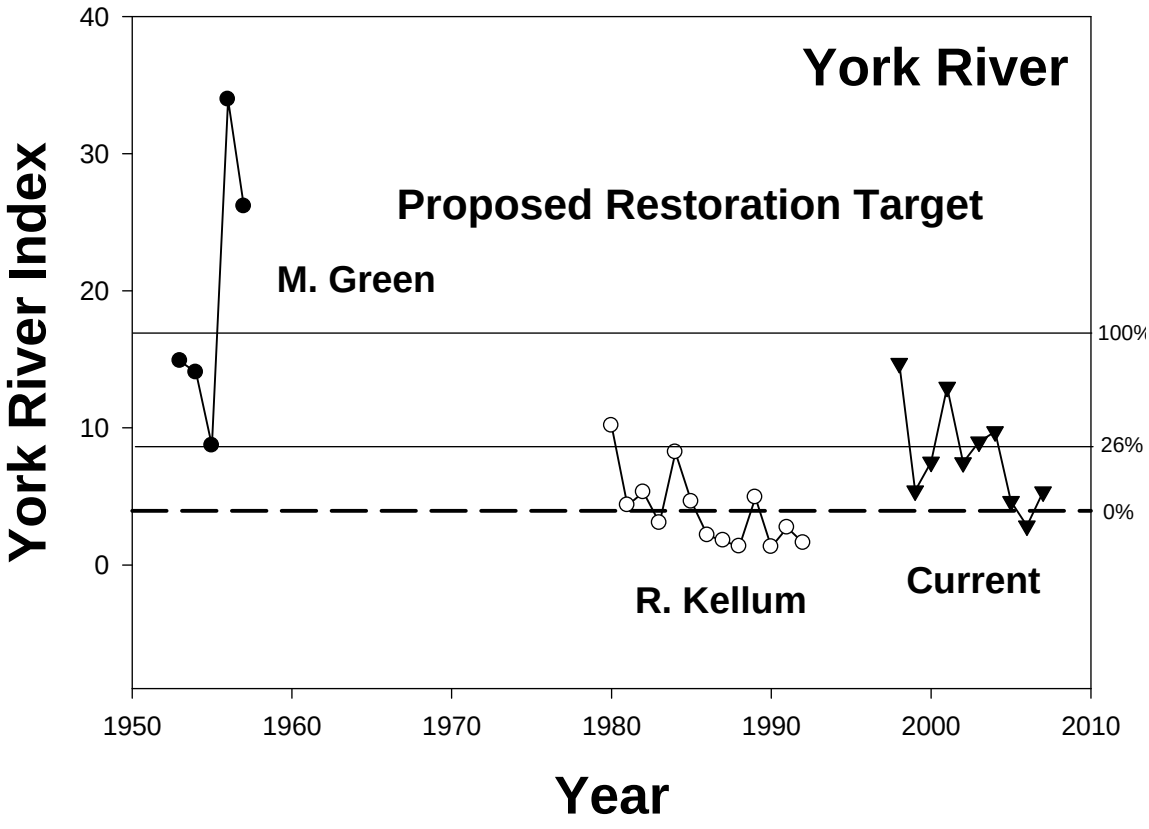


Figure 13. Comparison of recent (1998-2007) and historic (1980-1992) catch index values of American shad in the James River. Values of the catch index are calculated as the area under curve of daily catch versus time from commercial log books and from recent monitoring. Current monitoring is conducted on two successive days in each week from late February to the end of the run each year.

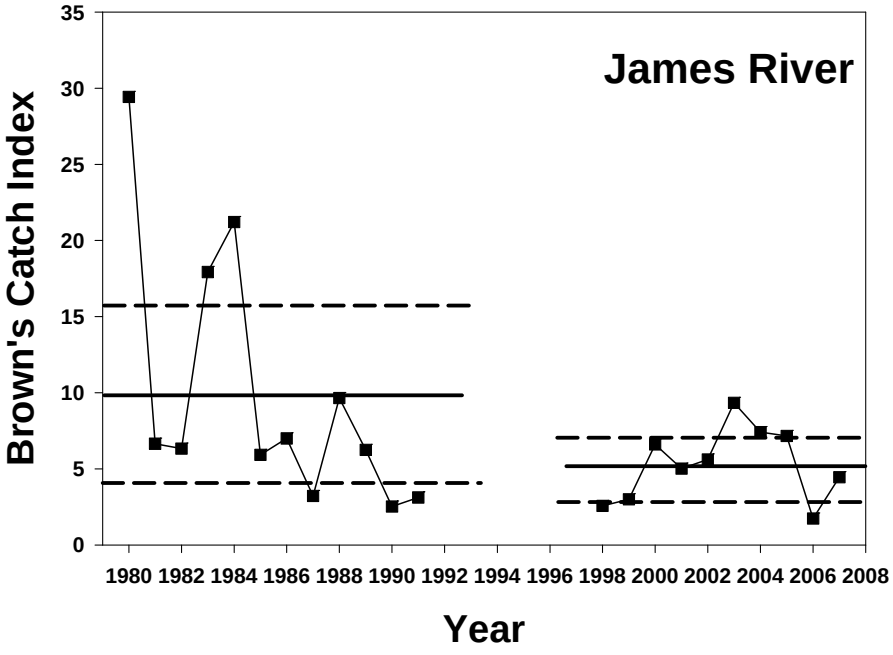
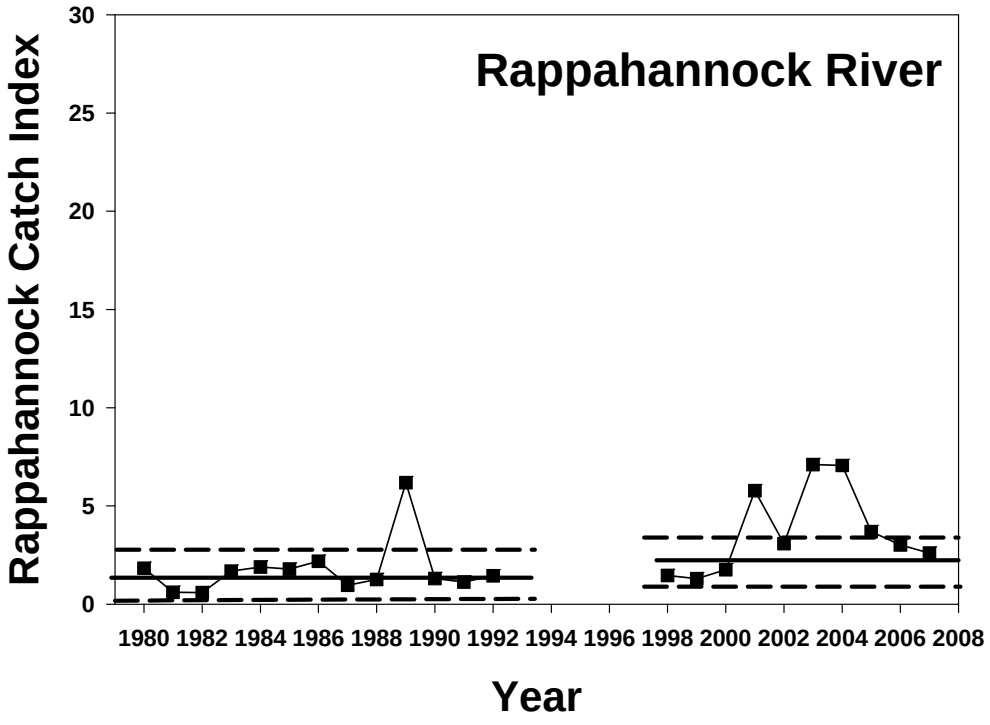


Figure 14. Comparison of recent (1998-2007) and historic (1980-1992) catch index values of American shad in the Rappahannock River. Values of the catch index are calculated as the area under curve of daily catch versus time from commercial log books and from recent monitoring. Current monitoring is conducted on two successive days in each week from late February to the end of the run each year



Appendix 2

Tracking the 2002 Year Class of American Shad Using a Natural Marker

Author:

Sally A. Upton

In response to ASMFC recommendations for stock-specific age validation of American shad, we are using a natural, geochemical marker in otoliths of members of the 2002 year class of American shad in the York River to evaluate age determination methods for the stock. Walther et al. (2008) identified enriched $\delta^{18}O$ values in otolith cores of juvenile American shad of the 2002 year class collected in the York River freshwater nursery grounds (Figure 1). The analysis of adult otolith cores, collected during spawning migrations in the York River, allows for identification of members of the 2002 year class based on $\delta^{18}O$ values, and comparisons between age as determined by geochemical data and age estimates made using the Cating (1953) method can be made. In an effort to evaluate additional structures for their use in age determination of American shad, age as determined by geochemical data is being compared to age estimates made using whole otoliths.

Currently, our study constitutes two years of data (2006 and 2007), encompassing age four and five individuals of the 2002 year class. A third year of data (2008) is being collected and will be added to the study to include age six individuals of the 2002 year class. We have identified individuals of the 2002 year class in collections of adult fish from 2006 and 2007 based on $\delta^{18}O$ values. Scale and whole otolith-based age estimates for those individuals identified by the geochemical data to be of the 2002 year class were examined and evaluated. Agreement between geochemical data and scale and whole otolith-based age estimates was low. Geochemical data indicated that a lower percentage of the catch in both 2006 and 2007 were of the 2002 year class than either scale or whole otolith-based methods indicated (Table 1). Scale and whole otolith-based age estimates were also not in agreement. Whole otolith-based methods indicated a lower percentage of the catch in 2006 and 2007 were members of the 2002 year class than scale-based methods did, but this percentage was still higher than that indicated by geochemical data (Table 1). Scales, otoliths, and geochemical data are being examined for each specimen to investigate the reasons behind the disagreement in aging methods. Despite the disagreement between methods, the geochemical data show expected recruitment patterns for the 2002 year class. Juvenile indices of abundance suggest that the 2002 year class of American shad in the York River is a very weak year class. This is reflected in the geochemical data in that few of the adults collected in 2006 and 2007 show evidence that they are members of the 2002 year class. American shad are believed to begin recruiting to the spawning stock at age three, with recruitment increasing thereafter. Peaks in recruitment are believed to occur at the ages of four and five (Maki et al. 2001). This pattern of increasing recruitment can be seen in the geochemical data for members of the

2002 year class. Inclusion of 2008 data will allow for continued tracking of recruitment of this year class.

The results obtained thus far are in agreement with the current understanding and with the findings of McBride et al. (2005) that age estimates for American shad using the Cating (1953) method of scale-based age determination may not be accurate and are often in disagreement with age estimates made using different methods. We expect that the inclusion of an additional year of data will only strengthen these conclusions by allowing for a third age class to be evaluated and providing additional material for age comparisons.

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Cating, J.P. 1953. Determining age of Atlantic shad from their scales. Fishery Bulletin 54:187-199.

Judy, M.H. 1961. Validity of age determination from scales of marked American shad. Fishery Bulletin 61:161-170.

Maki, K.L., J.M. Hoenig, and J.E. Olney. 2001. Estimating proportion mature at age when immature fish are unavailable for study, with application to American shad in the York River, Virginia. North American Journal of Fisheries Management 21:703-716.

McBride, R.S., M.L. Hendricks, and J.E. Olney. 2005. Testing the validity of Cating's (1953) method for age determination of American shad using scales. Fisheries 30 (10):10-18.

Olney, J.E. 2007. Age determination of American shad. American Shad Stock Assessment Report for Peer Review, Stock assessment report No. 07-01 (Supplement) of the Atlantic States Marine Fisheries Commission 1: 38-41.

Walther, B.D., S.R. Thorrold, and J.E. Olney. 2008. Geochemical signatures in otoliths record natal origins of American shad. Transactions of the American Fisheries Society 137:57-69.

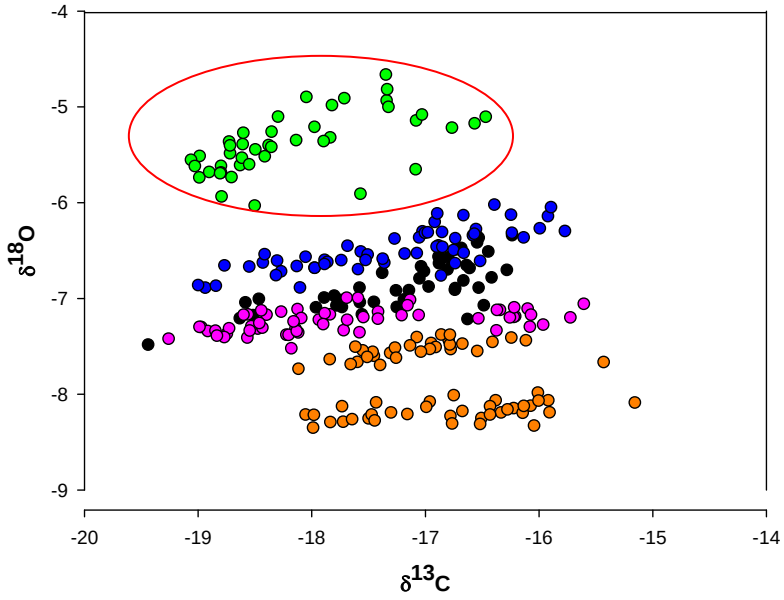

Figure 1. $\delta^{18}O$ and $\delta^{13}C$ values for otolith cores of juvenile American shad collected during the summers of 2000 (black), 2001 (blue), 2002 (green), 2003 (orange), and 2004 (pink) in the freshwater nursery regions of the York River. Data from 2002 are indicated by the highlighting circle. Data for 2000-2002 are from Walther et al. (2008).

Table 1. Percent of total catch (*n*) in 2006 and 2007 collections of adults that were determined to be of the 2002 year class based on geochemical, scale-based, and whole otolith-based age determination methods.

Year	**Method**	**Percent of Catch of 2002 Year class**	***n***
2006	Geochemical	6	189
	Scale-based	30	163
	Whole otolith-based	21	153
2007	Geochemical	21	305
	Scale-based	40	268
	Whole otolith-based	32	318

Appendix 3

Maturity schedules for seven year-classes and three stocks of American shad from the Virginia portion of Chesapeake Bay

Author:

Troy Tuckey

Determining maturity schedules is a fundamental component of stock assessment as restoration targets are often based on maintaining a portion of the spawning stock biomass in reserve to facilitate continued recruitment and a viable fishery. In addition to estimates of vital rates (e.g. growth, natural mortality and fishing mortality), estimates of adult biomass require knowledge about year-class strength and the maturation process, or the proportion of fish mature at a particular age. Delays or changes in age at maturity can modify when strong year-classes enter the spawning stock and may affect stock assessment models and management decisions. This study uses the methodology developed by Maki et al. (2001) to examine maturity schedules on a year-class specific basis (longitudinal approach) and to compare maturity schedules from neighboring stocks from the James, York, and Rappahannock Rivers. Nine years of data were available from the Rappahannock River (n= 1,581 female American shad), the York River (n= 3,398 female American shad), and the James River stocks (n= 2,220 female American shad). Seven year-classes had completed the maturation process to at least age 7 during the study and could be used in the longitudinal investigation (1993 – 1999). Almost all females were mature by age 7, however there were four American shad that matured at age 8. Year-class specific age at maturity estimates are grossly similar with most fish maturing between ages 4 and 6 in each of the three systems with peaks at age 5. However, there is sufficient inter-annual variability in the proportion maturing at age in each of the three rivers to continue to evaluate maturity schedules for the stocks separately. While most American shad were mature by age 5, the year-class specific estimates ranged from 50% to 85% mature in the James River, from 59% to 79% in the Rappahannock River, and from 60% to 87% in the York River. Consistent differences observed between the James and York River maturity schedules, and to a lesser extent with those from the Rappahannock River, shows that neighboring stocks that experience similar climate regimes can have stock-specific maturity patterns that persist through time. Maturity estimates for a particular age and year-class obtained using the cross-sectional approach do not always agree with the maturity estimates from the corresponding year-class and age obtained using the longitudinal approach. Because there is no other option available for forecasting spawning run strength, the cross-sectional approach still provides meaningful estimates.

Appendix 4

Replacement Indicator Information
Submitted to: Implementation Committee
Date: Thursday, January 24th, 2008

Name: Shad Abundance Indicator for the Chesapeake Bay

Status and Trends: Data for the York River will be provided by VIMS via an ongoing Catch per Unit Effort (CPUE) study involving American Shad gill-netting. Potomac River data is from commercial pound net bycatch and discard reports to the Potomac River Fisheries Commission. Data for the Susquehanna and James River will be provided by published fishway passage counts at Conowingo and Boshers Dams, respectively. Benchmark data was acquired from the ASMFC American Shad Stock Assessment from which the attached graphs and narration was taken. The current status of American Shad in the bay based on this 4-river metric will be computed as an abundance value.

Narrative Information and Data: See attached files labeled Narrative Information and Data. The files include language describing the replacement indicator, tables showing the sources of data and equations depicting calculations of the values

Source of Data: Fishway Passage Data from Conowingo and Boshers Dams, VIMS CPUE gill-netting data, Potomac River Fisheries Commission commercial pound net data.

Indicator Contact Information:

Nancy Butowski	MD DNR	nbutowksi@dnr.state.md.us	410-260-8268
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Marek Topolski	MD DNR	mtopolski@dnr.state.md.us	410-260-8263
Liana Vitali (staff)	CRC/CBO	vitali.liana@epa.gov	410-267-5718

Rationale for Replacement: It was widely agreed that the original shad abundance indicator which measured the number of fish lifted over Conowingo Dam in the Susquehanna River was not an accurate representation of American Shad abundance for the bay. This proposed replacement indicator combines peer-reviewed and historical data from four rivers throughout the bay and reconciles the values via weighted tables to produce a bay-wide value that can be tracked as a goal.

Pros and Cons:

Pro – Utilizing data from multiple river systems is more indicative of a bay-wide shad abundance indicator than fish lifts counts for one river

Pro – The ASMFC American Shad Stock Assessment is a peer-reviewed and widely accepted collection of data that a portion of the proposed Shad Abundance Replacement Indicator data is based upon (benchmarks, restoration goals, etc.). The methodology for the shad assessment (in each river) has passed peer review for the ASMFC stock assessment.

Con - Reconciling two different metrics (fish passage goals and catch levels) may appear to weaken the value of the indicator. However, by weighting the data by river and using peer-reviewed ASMFC and historical data, it is felt the value of the indicator can be justified.

Recommendation: LRSC and MASC recommend this indicator.

NARRATIVE INFORMATION AND DATA

American Shad

American shad were once the most abundant and economically important species harvested in the Chesapeake Bay and along the Atlantic Coast. Shad are anadromous fish like salmon, and spend most of their lives in the ocean returning to freshwater rivers to spawn after they reach maturity. Shad were a seasonal component of the diets of native people and early colonists, arriving at a time when food reserves were often at their lowest. During the mid 1880s, the harvest was measured in the tens of millions of pounds. By the mid-1970s, over-harvesting, decreased spawning habitat due to dam construction and other blockages, and poor water quality led to the decline of shad stocks.

Current management measures to promote the recovery of American shad in Chesapeake Bay include a moratorium on shad fishing with a limited bycatch allowance; the release of hatchery-raised fish; the removal of obstructions to migration; and the installation of fish passages. Over the last two decades shad stocks have been slowly rebuilding. In the last two years, some tributaries have shown signs of recovery (Potomac and York Rivers), while other areas have exhibited a decline (James and Susquehanna Rivers), but most river basins are at depressed levels of shad abundance.

In the past, bay-wide American Shad abundance was measured by the number of fish successfully lifted at Conowingo Dam in the Susquehanna River. It has since been widely agreed that a more comprehensive abundance indicator is necessary to adequately assess American Shad abundance throughout the bay. Scientists recently completed the Atlantic States Marine Fisheries Commission American shad stock assessment that included data from the Susquehanna, Potomac, York and James rivers. Historically, these shad stocks were major contributors to total shad landings in the Bay. Individual stock contributions

were weighted based on 1950s landings data that are believed to represent a relatively stable and reasonable level of abundance considering the reduction in access to available spawning habitat due to blockages such as dams. Progress towards recovery is judged relative to passage goals (the annual number of fish observed using fishways) or benchmark catch levels that are set by landings data from the 1950s (Table 1a).

The Susquehanna and James River counts are determined by fish passage data at York Haven and Boshers Dams, respectively (Table 1b). Assessment of the Susquehanna River was changed from shad passage at Conowingo Dam to shad passage at York Haven Dam to reflect the goal of 2 million shad passing the York Haven Dam annually. The Susquehanna River restoration goal of 2 million American shad above the York Haven Dam was developed for the 1981 FERC hearings during hydro-project relicensing. Research in the Connecticut and Columbia rivers estimated up to 50 American shad per acre during the spawning run. Available spawning habitat in the Susquehanna River was estimated (acres) and then multiplied by 50 shad per acre. The resulting estimate of 2 million American shad represents how many spawning shad can be supported above the York Haven dam assuming effective fish passage downstream. On the James River, American shad passage at Boshers Dam is compared to a passage goal of 500,000 shad. The James River restoration goal of 500,000 American Shad passed above Boshers Dam is based upon the number of American shad that can be supported by the 137 miles (11,930 acres) that became available following construction of the Boshers Dam fishway. The number of acres was multiplied by 50 shad per acre which is consistent with the Susquehanna River methodology and studies of the Connecticut and Columbia rivers. A total of 568,200 shad can be supported between Boshers Dam and Lynchburg, VA including tributaries in-between. The Boshers Dam fishway was sized to pass 500,000 shad annually (Table 1b).

Values for the York and Potomac Rivers are determined using gill-net data (Virginia Institute of Marine Science) and pound net bycatch and discard data (Potomac River Fisheries Commission), respectively. The 1950's commercial CPUE will be compared to the current commercial (Potomac River pound net) or fishery-independent York River monitoring CPUE. Catch-per-Unit-Effort (CPUE) measures the relative abundance of fish by standardizing the amount of fish caught by the amount of effort employed to catch the fish. The Potomac River CPUE measures the amount of American shad pounds caught per number of days the pound-nets are fished. The historic York River fishery used gill nets to target female shad for their roe. CPUE is computed based on the weight of female shad caught per meter of gill net per day and is calculated for each day the gill net is fished during the shad fishing season. However, gill nets are not fished during inclement weather. Therefore, the York River American shad index is not simply the CPUE since the gill net is not continuously fished. The index compensates for missed fishing days (due to inclement weather) by measuring the area under the curve of the 'CPUE per day of fishing season' relationship. The index is referred to as CPUE for the calculation shown. Restoration goal will be reached when present CPUE is equivalent to commercial CPUE observed during the 1950's. Percent progress to restoration target is computed as

$$\left(\frac{\left(\mathrm{CPUE}_{\mathrm{present}} - \mathrm{CPUE}_{\mathrm{low}}\right)}{\left(\mathrm{CPUE}_{1950\mathrm{s}} - \mathrm{CPUE}_{\mathrm{low}}\right)}\right) * 100$$

where $\mathrm{CPUE}_{\mathrm{present}}$ is the cumulative geometric mean CPUE since 2001 for each year; $\mathrm{CPUE}_{1950\mathrm{s}}$ is the 1950-1959 geometric mean CPUE, and $\mathrm{CPUE}_{\mathrm{low}}$ is the geometric mean CPUE from river-specific data representing the period of historic low abundance. Benchmark refers to $\mathrm{CPUE}_{1950\mathrm{s}}$ and baseline refers to $\mathrm{CPUE}_{\mathrm{low}}$ (Table 4). The bay wide indicator of shad abundance is the summed product of the river-specific weighting factors and their respective percent achievement of goal (Tables 1 and 2).

Percent progress towards goals remains low at fish passage facilities on the Susquehanna and James Rivers, whereas varied levels of achievement are evident in the York and Potomac Rivers. Shad passage in the Susquehanna and James Rivers has remained below 1% of each river's goal since 2000 (Figures 1 and 2). Percent of benchmark for shad relative abundance (CPUE) in the York River has increased from 37% in 2000 to 43% in 2001, then decreased to 28% in 2007 (Figure 3). In contrast, benchmark attainment in the Potomac River has increased from 12% in 2000 to 67% in 2007 (Figure 4). Annual percent achievement of the bay-wide goal has increased from 9% in 2000 to 21% in 2007.

The Chesapeake Bay restoration goal for American shad is an estimate of the spawning shad stock that can be supported with existing riverine blockages. The demographics and population dynamics of such a restored American shad population are unknown and the potential response to harvest has not been explored. Therefore, attainment of the Chesapeake Bay restoration goals is not connected to fisheries management decisions regarding this species. American shad are a coastal species; therefore, management decisions such as the harvest moratorium and allowable bycatch are determined by Atlantic States Marine Fisheries Commission (ASMFC). Additional information is available at www.asmfc.org/shadRiverHerring.htm.

Estimates of spawning success are measured by annual juvenile finfish surveys. The resulting juvenile abundance index (JAI) reflects the habitat quality for juvenile American shad. To date, no reliable relationship between JAI and adult shad returning to spawn has been detected.

Contributors to the Shad Abundance Indicator

The following individuals are affiliated with multiple Chesapeake Bay Program partners throughout the watershed. Dubbed the Shad Ad-Hoc Group, members met in late September to receive an update on the recently published ASMFC American Shad Stock Assessment and to discuss a replacement indicator for American Shad in the Bay. Conversation continued via email and phone calls until a draft report was produced. Representatives from CBP, MD DNR and VIMS have since worked on the draft report following recommendations from the CBP Indicators Workgroup, Living Resources Subcommittee and the Monitoring and Analysis Subcommittee.

Nancy Butowski (Group Chair)	MD Dept. of Natural Resources
Liana Vitali (staff)	CBP / Chesapeake Research Consortium
Joe Cimino	Virginia Marine Resource Commission
Pat Crewe	Virginia Institute of Marine Science
Jim Cummins	Interstate Commission of the Potomac River Basin
Mike Hendricks	PA Fish and Boat Commission
Tony Jarzynski	MD Dept. of Natural Resources
John Olney	Virginia Institute of Marine Science
Bob Sadzinksi	MD Dept. of Natural Resources
Jon Siemien	DC Fisheries
Dave Sutherland	US Fish and Wildlife Service
Jim Thompson	MD Dept. of Natural Resources
Marek Topolski	MD Dept. of Natural Resources
Alan Weaver	VA Department of Game and Inland Fisheries
Howard Weinberg	Univ. of MD, Center for Environmental Science
Dale Weinrich	MD Dept. of Natural Resources

Table 1a - Published landings data (thousands of pounds American shad rounded to nearest 1000 lbs)

Year	James[a]	York[b]	Potomac[a]	Susquehanna[c]			
1950	603		932	1162			
1951	619		877	1313			
1952	994		853	1244			
1953		552					
1954		602					
1955		538					
1956		716					
1957		638					
1958		386					
1959		463					
Geometric Mean Landings (available data)	719	547	887	1238		Total mean landings	3390
Proportion of landings (weight)	0.21	0.16	0.26	0.37		Sum of proportions	1

[a] Walburg and Sykes. 1957. Shad fishery of Chesapeake Bay with special emphasis on the fishery of Virginia

[b] Nichols and Massmann. 1962. Abundance, age and fecundity of shad, York River, VA, 1953-59.

[c] Walburg. 1955. Relative abundance of Maryland shad 1944-1952. (Totals from fishing areas 014, 016, and 018.)

Table 1b - Percent achievement of goal for the Susquehanna, James, Potomac and York Rivers since monitoring began in 2000-2001. For the Potomac and York, indicators, monitoring and commercial data are geometric mean CPUE.

	James	York	Potomac	Susquehanna		
Goal	500,000 fish passed	**Baseline** (CPUElow) = 3.22 **Benchmark** (CPUE 1950's) = 17.44	**Baseline** (CPUElow) = 2.9 **Benchmark** (CPUE 1950's) = 31.1	2,000,000 fish passed		
Method	# Fish Passed	Mean of Monitoring Data	Mean of Pound Net Data (Landings plus discard)	# Fish Passed		
Year : 2000	16	8.43	6.4	4,687		
2001	133	9.39	8.1	16,200		
2002	437	8.97	8.1	1,555		
2003	751	8.97	13.1	2,536		
2004	174	9.07	13.6	219		
2005	79	8.35	16.3	1,772		
2006	46	7.41	19.6	1,973		
2007	84	7.17	21.7	192		
Current % of goal	0.02%	28%	67%	0.01%		
Contribution to Bay-wide Goal	0.000042	0.044831	0.174462	0.000037	Pecent Achieved Bay-wide Goal	21.94%

Table 2 – Geometric mean landings, relative contributions and current levels of achievement toward recovery for major stocks of American shad in Chesapeake Bay. These values were used to calculate a bay-wide indicator of shad abundance relative to historical levels for 2007.

Stock	Goals and benchmarks: fish passed or CPUE	Status in 2007	Percent Achievement of Goal	Relative contribution to bay-wide indicator	Sum (% Goal Achieved x Relative Contribution)
Susquehanna	2,000,000 (shad passed)	192 (shad passed)	0.01%	0.37	0.000037
Potomac	31.1 (CPUE)	21.7 (CPUE)	67%	0.26	0.174462
York	17.4 (CPUE)	7.17 (CPUE)	28%	0.16	0.044831
James	500,000 (shad passed)	84 (shad passed)	0.02%	0.21	0.000042
Bay-wide Goal				1.0	**.2194 or 22%**

Figure 1 – Percent of goal achieved for American shad in the Susquehanna River.

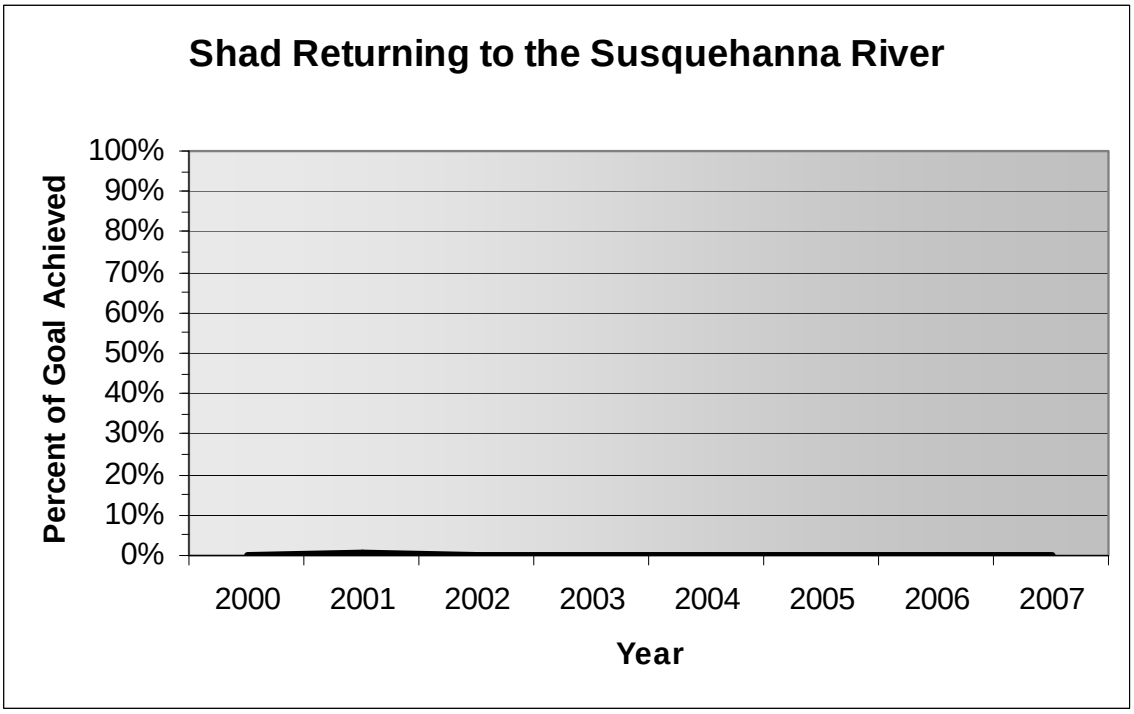


Figure 2 – Percent of goal achieved for American shad in the James River.

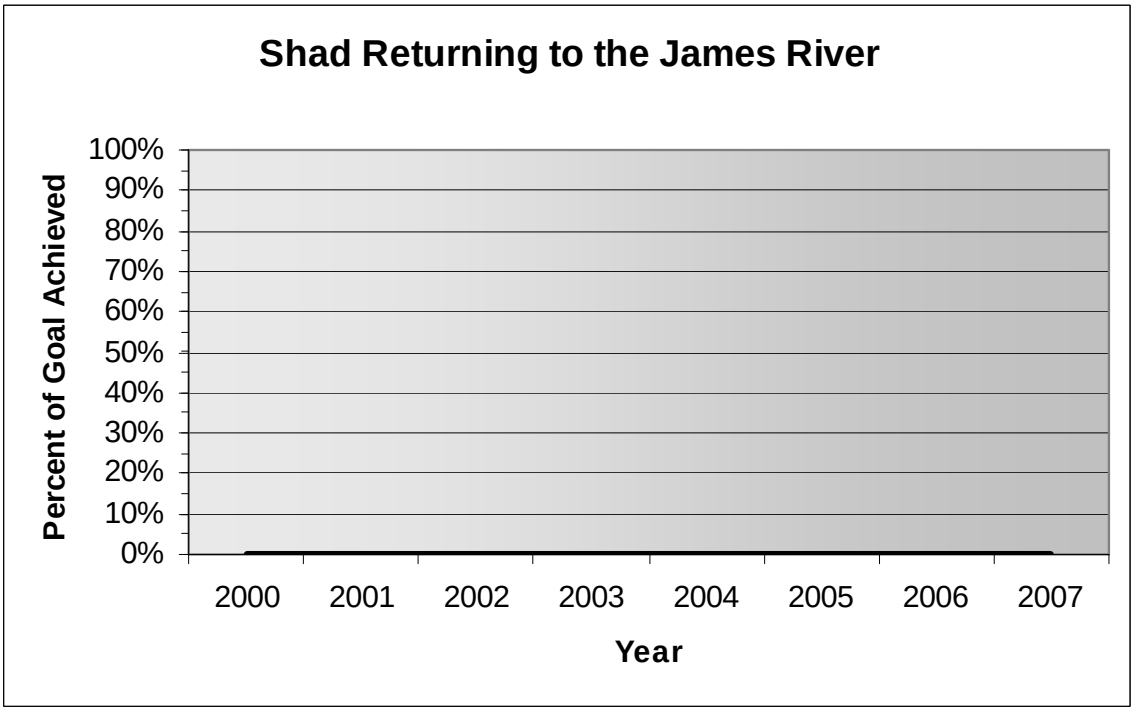


Figure 3 – Percent of goal achieved for American shad in the York River.

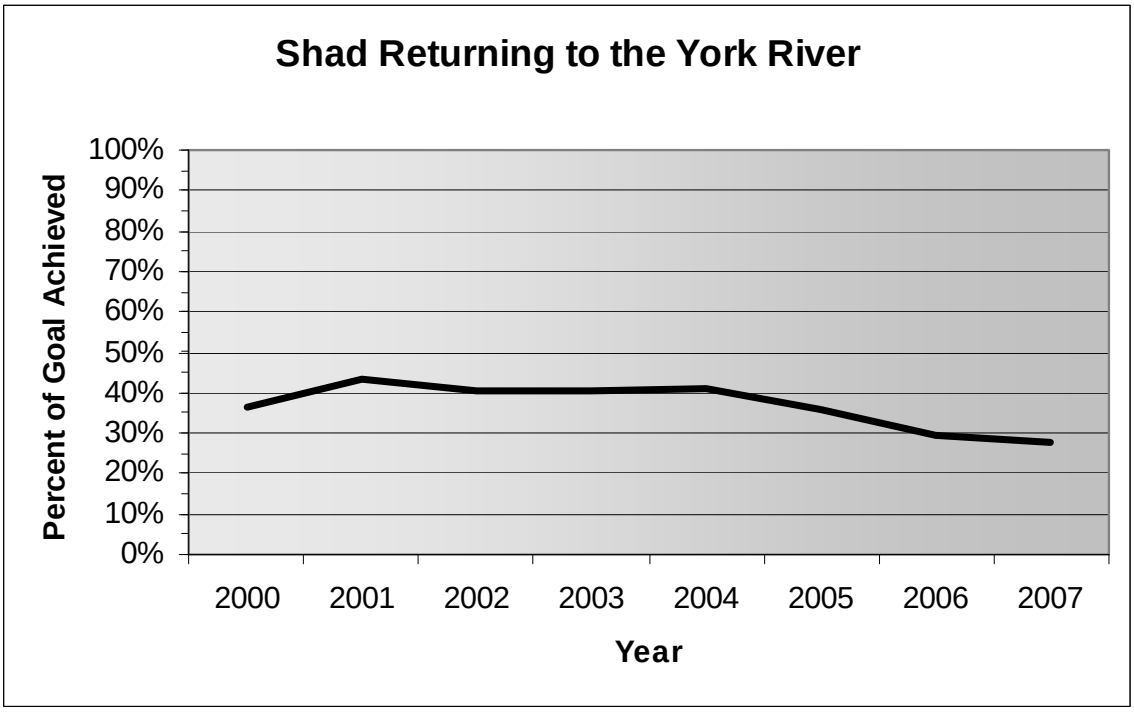


Figure 4 – Percent of goal achieved for American shad in the Potomac River.

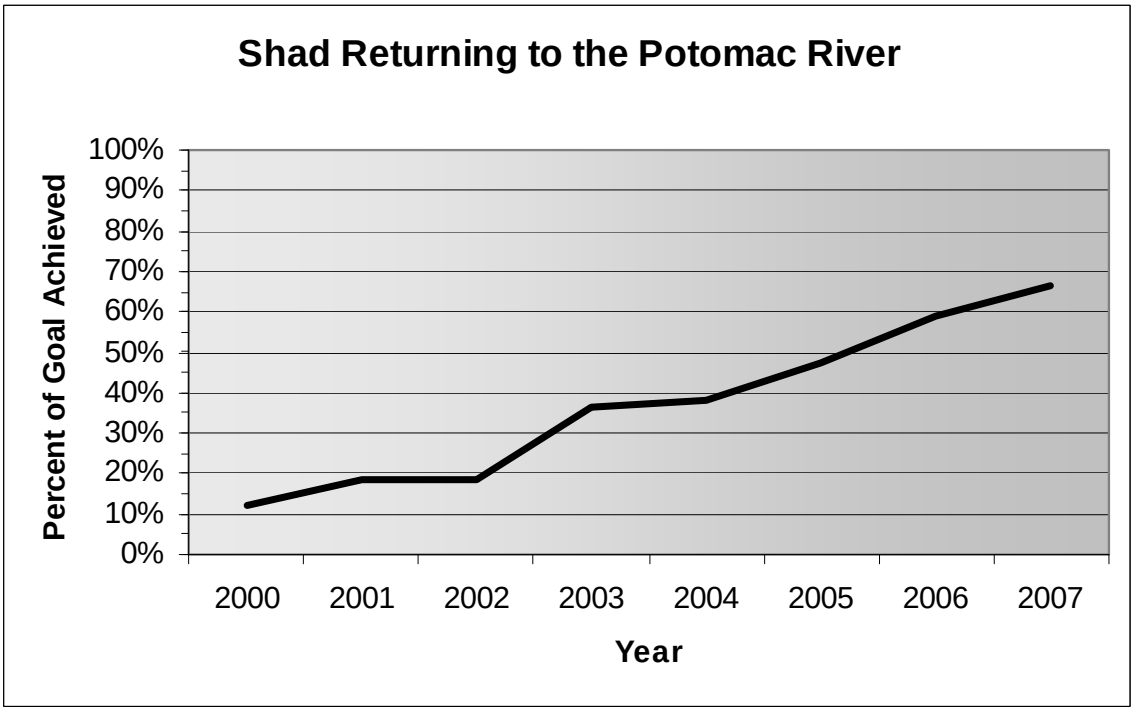
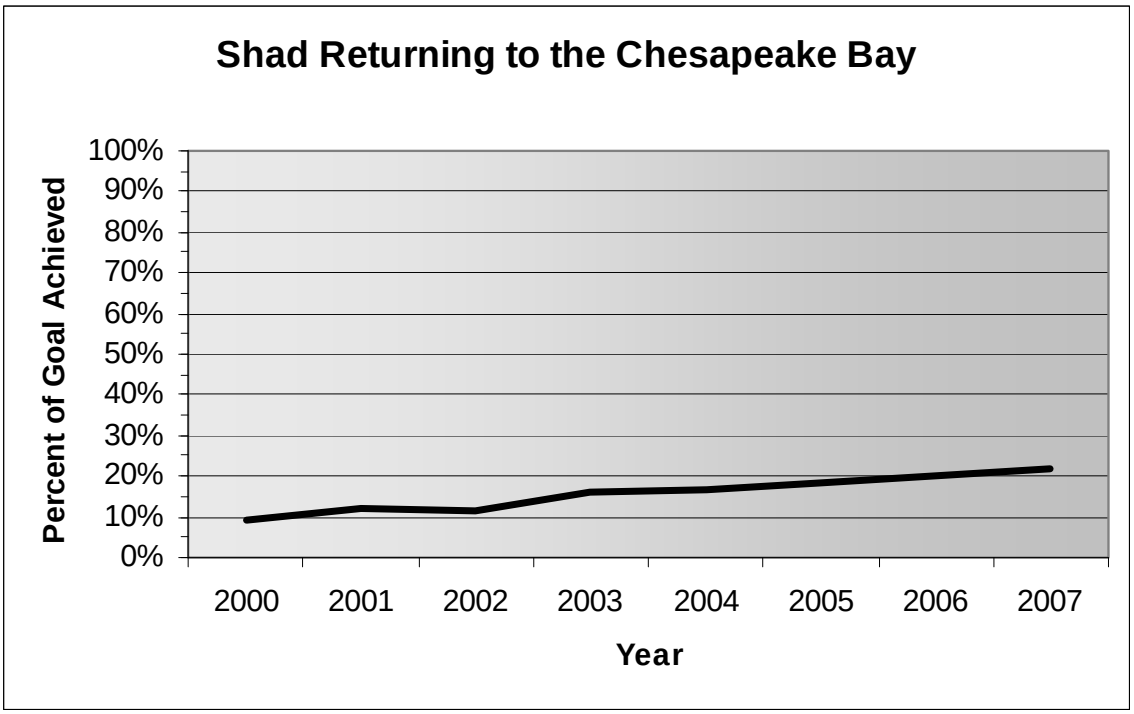


Figure 5 – Percent of goal achieved for American shad in the Chesapeake Bay.



Calculating the York River Index

American shad monitoring in the York River utilizes a staked gill net that is fished two days per week except during inclement weather. The methodology used in the York River is the same as that described for similar monitoring of the shad run in the James River (Olney et al. 2003).

Total pounds of pre-spawning female shad caught per day is divided by the length of the gill net in meters, which is the CPUE.

$$CPUE_{day} = \frac{pounds_{total}}{meters_{net}} \tag{1}$$

Catch data (CPUE) from each river is summarized as a catch index; the area under the curve of daily catch rate versus time of year (J. Olney, personal communication, January 9, 2008). In other words, the area being measured is between the x-axis and the function that is constrained by points A and B on the function (Figure 1). In the monitoring data, catches on two successive days are separated by up to five days (usually Tuesday-Saturday) in each week of sampling. In some rare cases, catches are separated by more than five days. We estimate catches on skipped days using linear interpolation between adjacent days of sampling. The index is calculated according to the trapezoidal rule as follows:

$$CI_{areal} = \tfrac{1}{2}\sum_{i=1}^{n-1} D_i\left(R_i + R_{i+1}\right) \tag{2}$$

where D_i is the number of days between cruise i and cruise i +1, n is the number of cruises, and R_i is the geometric mean cruise catch rate for cruise i. Because the sampling sometimes started after the first appearance of fishes and ended before all fishes had left the area, the catch is assumed to be zero $0.5D_1$ days before the first cruise and $0.5D_{n-1}$ days after the last cruise.

The catch index is then natural log (ln) transformed. The geometric mean is then calculated for all years since 2001 (cumulative measure of CPUE) by taking the antilog of the average natural log transformed catch index values.

$$GM = e^{\frac{\sum \ln}{n}} \tag{3}$$

Literature Referenced

Olney, J. E., D. A. Hopler, Jr, T. P. Gunter, Jr, K. L. Maki, and J. M. Hoenig. 2003. Signs of Recovery of American Shad in the James River, Virginia. *In* Biodiversity, Status, and Conservation of the World's Shads. American Fisheries Society Symposium, Bethesda, Maryland: 323-329.

Figure 1. Conceptual diagram for area under the curve estimation. The example is based on historical catch data from a commercial log book in 1984 (J. Olney, personal communication, January 9, 2008).